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Introduction

0

I firmly believe that, aside from your brain, a good map is the most useful navigation tool you can use.

Two forces have led me to develop the material in the pages of this book. The first is the progress that has been made in GPS receivers. The second is the availability of specialized maps, aerial photography, and satellite images.

An outdoors adventurer can now purchase a lightweight, rugged, and reliable GPS receiver for around $100. You can also use your smartphone's built in GPS with a free or low cost app. My favorite app is Gaia GPS. While an abundance of features is not necessary, the most common use of a GPS receiver is to get coordinates that allow you to locate yourself on your map. But to truly harness the power of the GPS for this purpose, it requires an understanding of coordinate systems, map scales, and map datums. These are new skills, even for seasoned backcountry navigators, but once mastered, they can empower you to navigate with confidence in any outdoor setting.

The days when the only maps you would likely be using were the topographic map series published by the USGS are long past. Maps and imagery are now readily available for download on the Internet. Many wilderness users are printing their maps right from their computers. But again, for this to be successful, it is necessary to have a good understanding of coordinate systems, map scale, and map datums.

In this guide, I introduce the user to Universal Transverse Mercator (UTM) coordinates using two different units of measure, meters and kilometers. I find the kilometer units to be intuitive and very easy for a beginner to grasp. Most users are working with a one-kilometer map grid and then measuring a fractional distance within the grid. Some folks have named this "kUTM". Some folks like it, others hate it. I've made a point of always including the unit of measure with coordinates in this booklet both because it is always good practice to write the unit of measure along with a measurement, and to help prevent any confusion on the part of the reader between the two formats. Hopefully, this reassures you that UTM coordinates are not as complex as they may seem at first, and that with a little practice, you'll be able to work with whichever format works best for your circumstances.

Quick Start Using UTM Coordinates

1

Setup Your GPS to Use UTM Coordinates

Using the setup menus for your GPS, set the position display format to UTM or UTM/UPS.

While in the setup menus, you should also set the map datum to match the datum of the map you are using. In the Continental United States, you are likely to encounter only three datums. They are, WGS84, NAD83, and NAD27 CONUS.

Most paper topographic maps published by the USGS for the Continental United States use NAD27 CONUS for their datum. Other map series may use one of the other datums. Check the "fine print" for a datum listing.

Locate the UTM Grid on Your Map

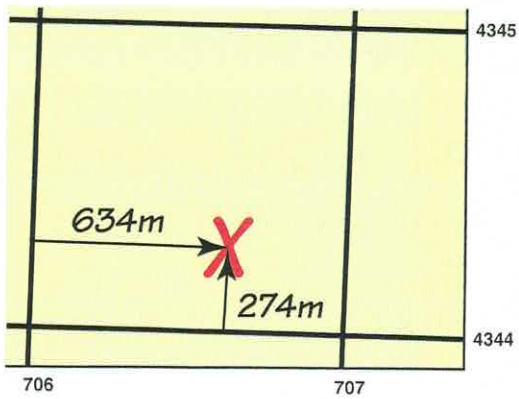
On a 1:24,000-scale map, a UTM grid consists of a square grid with grid lines spaced 1 kilometer apart. The coordinate values for these grid lines will be printed along the edges of the map. Many maps do not have grid lines printed on them. They only have tic marks (usually light blue in color) along the edges, and you will need to connect the tics to draw the grid. Other map scales may have different spacing between their grid lines.

Refer to this guide's *Locating Coordinate Grid Information* section for more information.

A UTM Coordinate Consists of an East-West Position and a North-South Position

UTM coordinates are east-west and north-south positions measured using metric distance units of either meters or kilometers. By convention, the east-west distance is always first referred to as the easting. The easting increases from left to right (west to east). Next is the north-south position, called a northing. Northings increase from bottom to top (south to north). A complete UTM coordinate also includes a zone. The zone is an integral part of the UTM coordinate when it is used on a global scale. However, we will

discuss it later in this guide since it has little impact when working in a localized area.



The UTM coordinates of the red X are 706.634km E 4344.274km N.

kUTM

a one-kilometer grid square, it is convenient to write the easting and northing values in kilometers. The portion of the coordinate to the left of the decimal point represents full kilometers and corresponds to the UTM value for the grid line found along the edge of the map. The digits to the right of the decimal point represent fractions of a kilometer and are measured within the one-kilometer grid square on the map.

One kilometer is equivalent to 1000 meters. Thus, converting between UTM coordinates written in kilometers or meters is easy.

These two coordinates are equivalent:

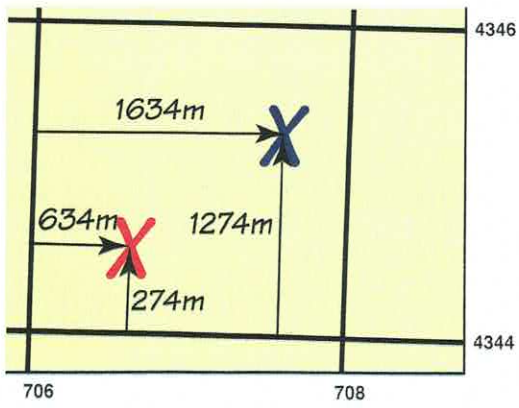
706634m E	**706.634km E**
4344274m N	**4344.274km N**

It is nearly impossible to measure with more than a 10m accuracy on a 1:24,000-scale map. Thus, it is common to drop the 1m digit in a UTM coordinate written in kilometers. When writing the coordinate values in meters, use a zero as a placeholder for digits beyond the measurement precision. Our example would become 706630m E 4344270m N or 706.63km E 4344.27km N.

The key concept here is understanding how to divide the easting and northing so that you know which digits to use in locating the grid square and which digits represent the distance to be measured or estimated within the grid square. For a 1000-meter grid square, the 1's, 10's, and 100's digits make up the distance within the grid square, and the 1000's and larger digits identify the grid square. I find it helpful for beginners to draw a small vertical line separating the two parts of the easting and northing coordinates. If you are using the kUTM format, the decimal place marks the division of the two parts of the coordinates.

706|634m E	**706.634km E**
4344|274m N	**4344.274km N**

When the grid size is not a multiple of 10, the coordinate values do not divide as neatly. In this situation, it's helpful to remember that both the easting and northing are just distance measurements. A larger part of the values will specify the grid square, and the remaining part of the values will be measured within the grid.

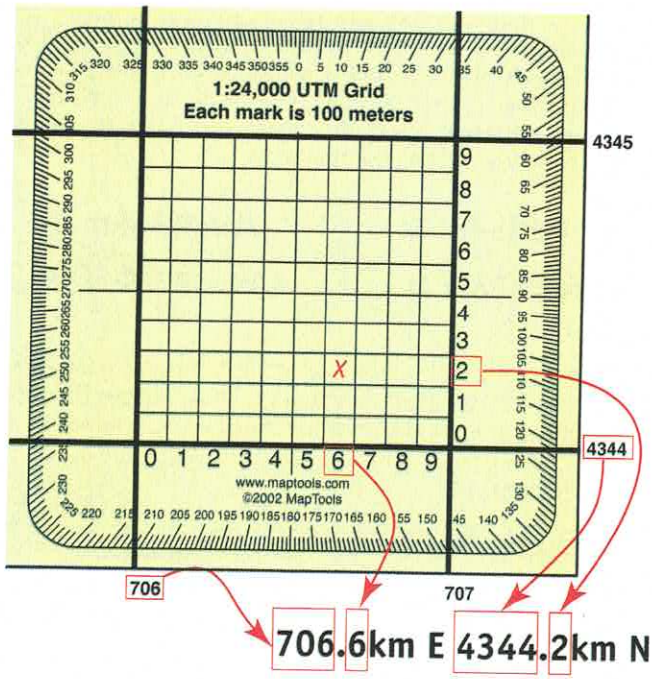


A Tool to Measure Within the Grid Square

To determine coordinates with more precision than the grid square on the map, you will need a small measuring tool that matches the scale of your map and that is marked in metric distance units. Use this tool to measure position within the grid square. Refer to the *Tools to Measure within the Grid* section of this guide for more information.

The grid tool in the back of this guide is an example of such a tool. It is designed to work with a 1km grid on a 1:24,000 scale map. The tool divides

the 1km grid into 100 smaller grid squares, each a tenth of a kilometer (100 meters) on a side.

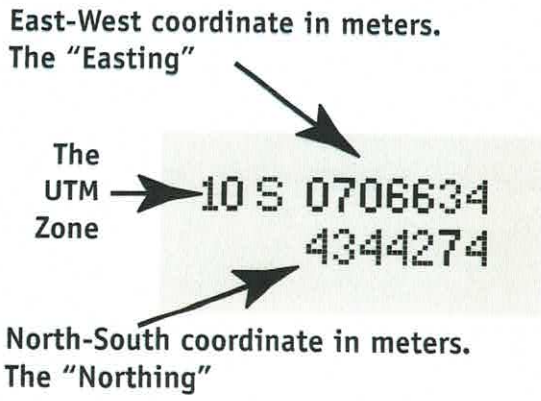


Since the tool measures with 0.1km (100m) accuracy, it is common to write the coordinates with the same level of precision. In this case, 706.6km E 4344.2km N. A 100m grid square is about the size of two football fields placed side by side. While this is sufficient for many applications, some demand greater accuracy. Other tools with finer markings can measure position within the grid with 10m accuracy. Measuring with more than 10m accuracy on a 1:24,000 scale map is impractical.

UTM Coordinates on Your GPS

GPS receivers typically display UTM coordinates in meters. Standing at the red X, your GPS would display the coordinates like this.

UTM Coordinates displayed on a typical GPS receiver



To convert from meters to kilometers add a decimal point three digits in from the right, between the 1000m and 100m digits. Now, it is easy to separate the digits we use to locate the 1km grid square from the distance we measure within the grid square.

Our example becomes:

0706.634km E
4344.274km N

To plot this on the map, we need to locate the 706km E 4344km N grid square. Then, within the grid, we need to measure an additional 0.63km to the east and 0.27km to the north.

Try out your skills with the practice map and problems located later in this guide.

Why Use UTM Coordinates

2

Benefits Offered by UTM Coordinates

A square grid

UTM provides a constant distance scale anywhere on the map. In the angular coordinate system of latitude and longitude, the distance covered by a degree of longitude differs as you move towards the poles and only equals the distance covered by a degree of latitude at the equator. With UTM coordinates, the north-south and east-west measurements are the same.

No negative numbers

No east-west or north-south designators

Grid values increase from left to right and bottom to top

This is like the X Y Cartesian coordinate system you learned in high school math class. Simple Cartesian coordinate mathematics can be used. No spherical trigonometry is required!

Coordinates are decimal-based

Ones, tens, hundreds, and so on. No more minutes and seconds to convert.

Coordinates are measured in metric units

All UTM coordinates are measured in metric distance units of meters or kilometers. The UTM system allows the coordinate numbering and distance measuring systems to be identical. Most of the world has already adopted the metric system. You won't need to remember how many feet are in a mile. And what's that in yards?

A Few Reasons Not to Use UTM

No UTM Coordinate information on the map

While every USGS map produced since the 1940s has UTM coordinate information, this is not true for every map you may encounter. The coordinate markings on your map will be a factor in choosing the coordinate system you use. It is possible to add a UTM grid to a map. Refer to the section on that topic later in this guide for more information.

Your user community has standardized on another coordinate system

Most aviation and marine users have standardized on using latitude-longitude coordinates. GPS receivers explicitly designed for aircraft or marine use may not support UTM, and their users are unlikely to be familiar with UTM coordinates. While this may make it necessary to use lat/lon coordinates when communicating with these resources, you may find it easier to convert the coordinates to UTM to plot them on your map. Your GPS will display a stored position in whatever position format you specify. Thus, you can use your GPS to convert between coordinate systems by storing a position, changing the position display format, and then recalling the stored position.

Don't become a coordinate Zealot

Be flexible in your choice of coordinate system. Though UTM is often easier to plot on a map, lat/lon is still widely used. Suppose you learn to work with both and use your GPS to convert from one format to another. In that case, you will be able to work with many map users, different types of maps, various computer systems, and publications that have chosen one coordinate system over the other. Don't get stuck thinking that there is "only one proper coordinate system" and that everyone should be made to use your chosen format.

Setting Up Your GPS to Use UTM

3

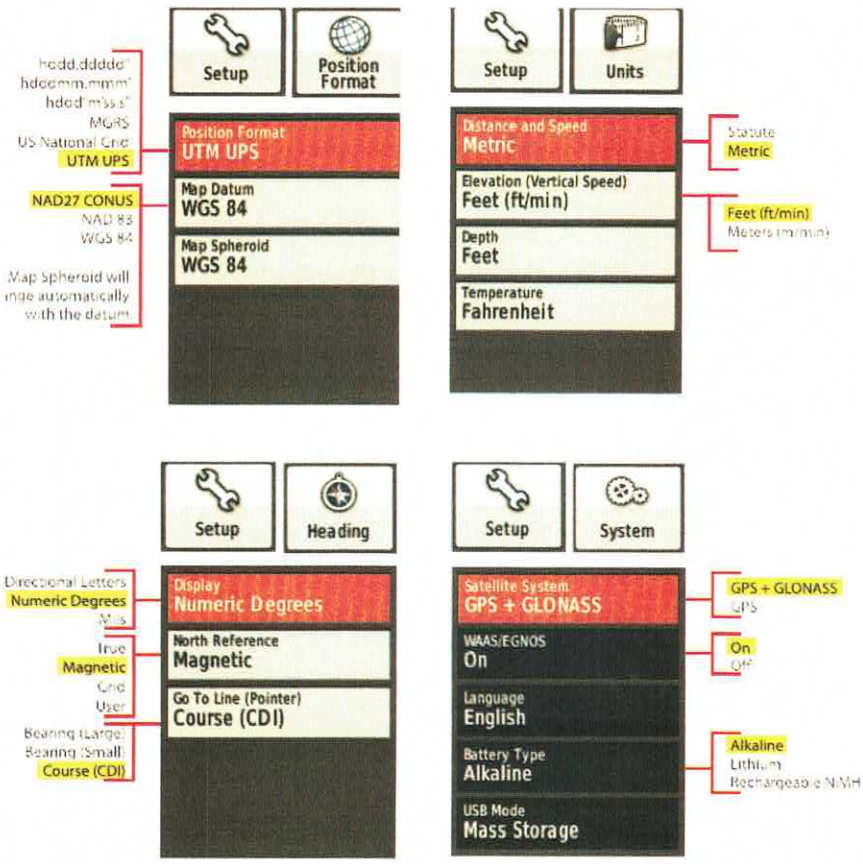
Almost every GPS receiver currently available for land-based recreational users supports the UTM coordinate system. However, GPS receivers designed as car navigation systems or built into cellular phones typically will not display UTM coordinates. Some may not even provide coordinates for your current position in any format.

Your GPS receiver probably came from the factory configured to display your position in lat/lon coordinates. You will need to change the settings for your GPS to display your position using UTM coordinates.

The examples on the following pages show screens from a Garmin eTrex 20. Your GPS receiver's menus and screens will likely differ, but similarly named menus and selections should be available. You may wish to refer to the manual that came with your GPS for specific details.

Setup

The first step is to locate the Setup menu. On the Garmin eTrex GPSs, you can access the Setup Menu by selecting the Setup icon in the Main Menu. The most commonly changed setup pages are pictured below with their most common options.



The two most important settings are the Position Format and the Map Datum. Setting the North Reference and the Distance and Elevation Units is also helpful.

Position Format Menu

This is where you will select UTM/UPS to instruct the GPS to display coordinates in UTM format. You will see many different formats to choose from. The most common choices are:

UTM/UPS
MGRS
US National Grid
hddd° mm.mmm'
hddd° mm' ss.s"
hddd.ddddd°

MGRS and USNG are specialized forms of UTM, which will be discussed later. The last three are latitude/longitude formats.

Map Datum

Setting the map datum is essential when using the GPS coordinates with a map. **The map datum setting on the GPS must match the datum of your chosen map.** Failure to set the correct datum is a common error, resulting in positions that are consistently several hundred meters off. The most common choices for map datum include:

NAD27 CONUS
NAD83
WGS84

NAD27 CONUS is shorthand for the North American Datum of 1927 – Continental United States. NAD27 CONUS is the datum used on most paper topographic maps printed by the USGS.

WGS84 is the default datum for most GPS receivers and is commonly used on most modern navigation charts. This guide provides more information on Map Datums in a later section.

NAD83 is essentially the same datum as WGS84. It was established as a North American datum just before its adoption as a worldwide datum.

Distance and Elevation Units

Your choice of distance and elevation units is mainly based on your preference. Some GPS receivers will let you select distance and elevation units separately, while others combine the selection. The two most common choices are Metric or Statute Miles and Feet.

Since you are using UTM coordinates, which use metric-based units, it makes sense to select metric distance units. Your map is gridded in 1km grids, and you probably have some tool that you can use to measure within the 1km grid. Thus, it is easy to measure metric distances on your map.

If you can set elevation units separately, setting them to the same units as the contour lines and elevation markings on your map is sensible.

North Reference

Your choice of North Reference will determine the 0° or North reference for headings and bearings displayed by your GPS. This will impact how you plot bearings from the GPS on your map and how you use your compass with these values. The most common choices include:

True
Magnetic
Grid

Choosing True will result in directions that are referenced to True North. On most maps, the left and right edges are lines of longitude, which also represent a True North reference.

Choosing Magnetic will result in directions that are referenced to Magnetic North. These directions will match up with compass readings taken with a compass that has not been adjusted to compensate for the local declination. Some GPS receivers split this option into two choices: one will automatically calculate the declination for your current location, and the other will let you manually enter the declination you wish to use. If you want the GPS values to match the readings on your compass, choose the automatic option.

Choosing Grid, will result in directions that are referenced to Grid North. Grid North is referenced to the UTM grid lines on your map. Grid North is a convenient north reference for plotting bearings on the map since the map has many grid lines that make handy north reference lines.

Additional information can be found in the *North Reference* section later in this book.

User Configurable Data Fields

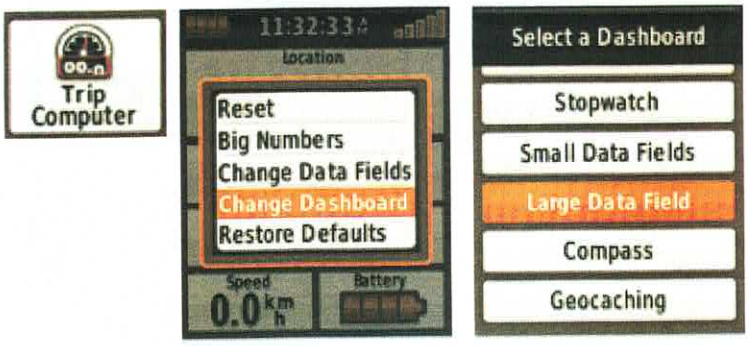
The Trip Computer, Compass, and Map each have user-configurable data fields. The choices shown here reflect my personal preferences and are how I recommend my navigation students set up their GPS receivers.

Having everyone's GPS set up to display the same information in the same locations is desirable if you work with a group. Garmin has a feature called Profiles, which allows you to save the setup and data field configuration. To create a new profile, select Setup, Profiles, and Create Profile

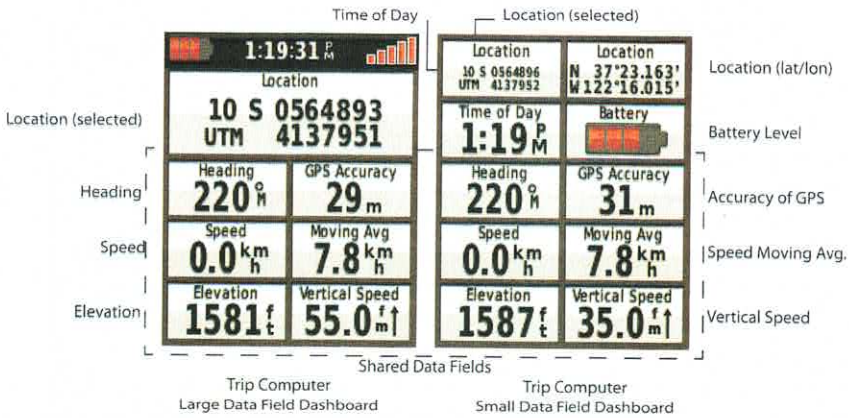
Trip Computer

The top of the Trip Computer is called the Dashboard, which can also be configured.

From the main menu, select the Trip Computer, press the menu button, select Change Dashboard, and select Large Data Field.



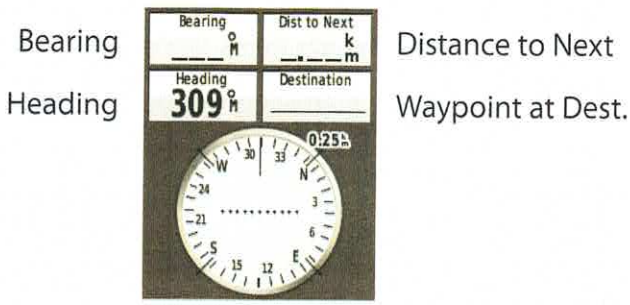
Then press the menu button, select Change Data Fields, select the individual data fields, and configure them as shown below.



When you are finished changing data fields, press the back button to exit the change mode.

Compass Display

You should also change the data fields on the Compass screen.



Map Display

I prefer that there are no data fields on the Map screen.

Press the Menu button while viewing the Map screen, then select Setup Map. Then select Data Fields and set it to 0.

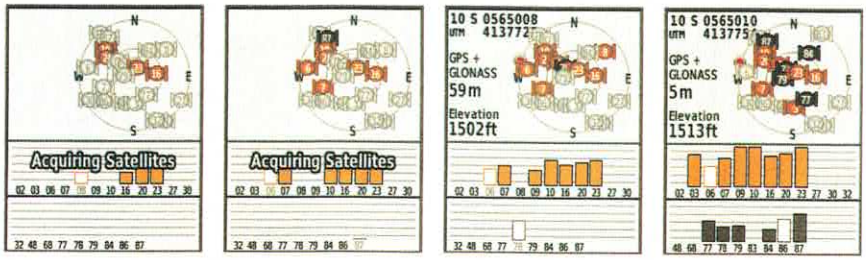
Using Your GPS

4

Satellite Signal Acquisition

Before your GPS can calculate your position, it must receive and synchronize with the signals from at least four satellites. Typically, you will see a screen showing the progress of this synchronization. The time required to acquire the signals will vary. If it has been many days since you last turned the unit on, or you have moved several hundred miles or more from the location where you last turned it on, it will have an outdated model of the positions of the satellites in the sky and will thus take longer to synchronize.

On a Garmin eTrex, the start-up sequence looks like this:



Once its position has been calculated, many GPS receivers will automatically switch to a display of your current position. Others require you to select the position display screen yourself.

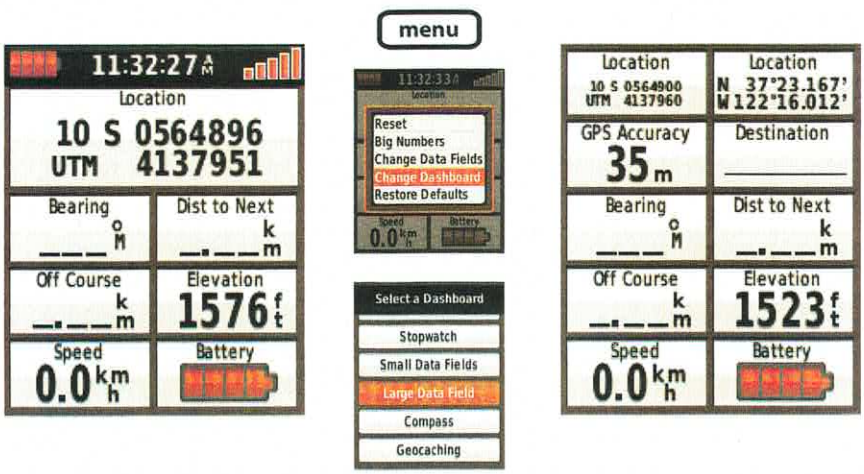
You should develop the habit of checking the estimated accuracy of the position computed by your GPS. This is especially important when determining the coordinates of a small item you wish to return to using these coordinates. Most GPS units will provide this accuracy information on the screen that displays the satellite status. You will want to see small numbers. Less than 20m (60ft.) is expected. With good conditions, values less than 10m are likely. A few GPS units display the estimated position error on the same screen that the coordinates are displayed. In the author's opinion, this is the right place to display it! Extra points if it also shows the datum on this screen as well.

Your Location

The Trip Computer will be able to show you the coordinates for your current location.

When I'm using UTM but working with folks that may need lat/lon,

I prefer to use the Small Data Field Dashboard configured to show UTM and lat/lon coordinates.



The coordinate location display is what I use most often when I'm using my GPS to assist with navigation. I leave the GPS unit turned off and store it away most of the time. Occasionally, I want to confirm my location on the map, or someone else has requested my current position. I power up the GPS, wait a minute for the computed position to stabilize, and read my UTM coordinates. As described in the following chapters, I can quickly locate my rough position on my map, or if something more precise is required, I can use a plotting tool to mark a precise location.

My GPS, combined with simple coordinate plotting skills, allows me to know my position on my map anywhere on the surface of the earth with an accuracy of about two parking places. My GPS receiver is faster than almost all other position-finding techniques in my toolbox. It works in the dark and in different situations where visibility is poor. With occasional use, as I have described here, the batteries will last for months.

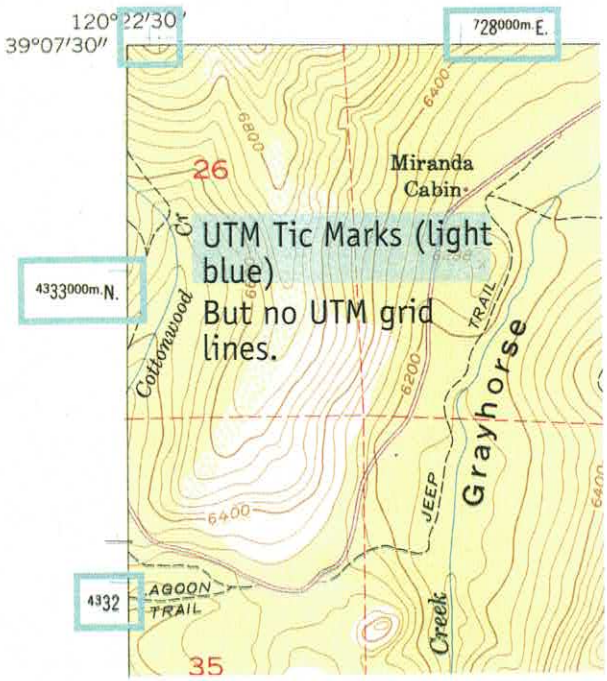
Locating Coordinate Grid Information on USGS Maps

5

Locating the coordinate grid for your desired system on the maps you plan to use is a straightforward process. The examples provided here are from USGS 1:24,000 scale maps, but the notations are similar on most maps, making it easy for you to navigate.

UTM 1km Grid Square

Some USGS maps have the 1km UTM grid printed using thin black lines spaced 1km apart. See the blue highlighted examples on the next page. Other USGS maps only have light blue tic marks along the edges, indicating the position of the UTM grid line. You will need to draw the grid lines yourself. See the example map to the right.



Some maps label the UTM grid tics with the full coordinate value in meters. Others use an abbreviated label at most tics showing only the digits of the coordinate used to locate the grid line. On a map with a 1,000m grid, the right-most three digits of the coordinate will be left off. On a map with a 10,000m grid, the right-most four digits of the coordinate will be left off. Maps with these abbreviated coordinate labels usually show the full coordinates in meters on two or more corners.

Maps designed for use with MGRS or USNG coordinates will typically show the abbreviated coordinate label using two type sizes. The 10,000 meter digits and larger will be shown with a smaller type size. The smaller type digits are omitted when reporting an abbreviated coordinate. See the *MGRS and USNG* chapter for more information.

When other information printed around the margin of the map is deemed more important and would interfere with the coordinate tic label, the label is omitted.

Lat/Lon 2.5 Minute Grid Rectangle

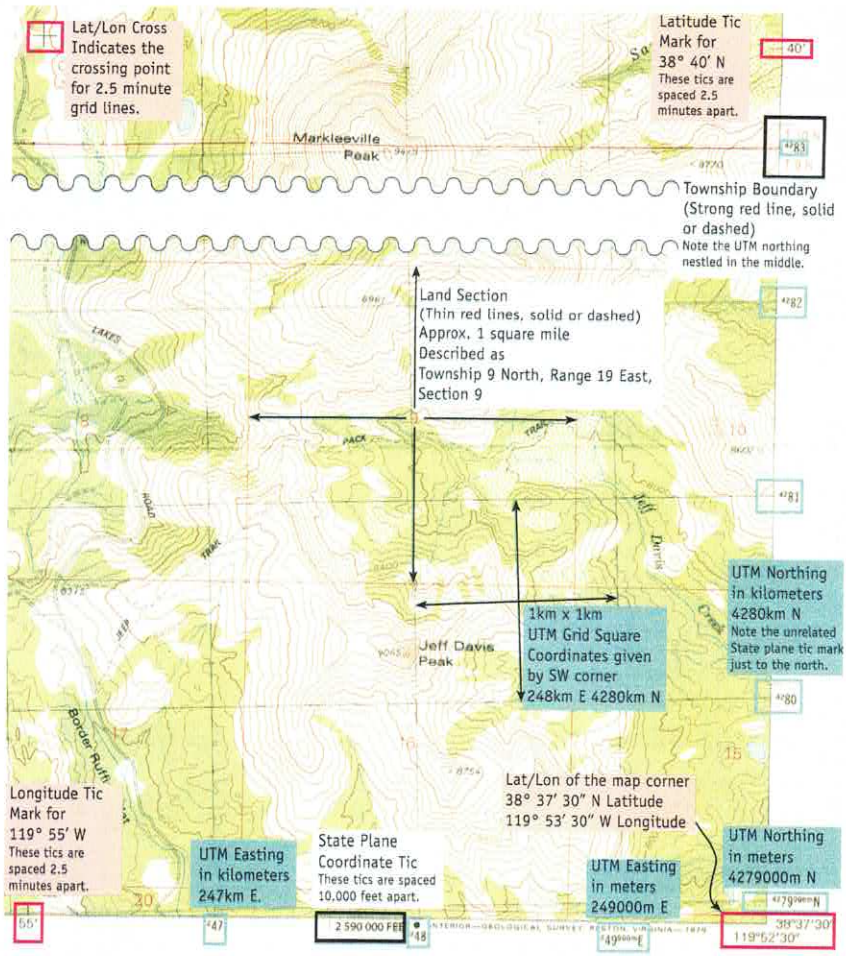
If you choose to use lat/lon coordinates, you will need to draw the lat/lon grid lines. Connect the ticks on the edge of the map with the crosses in the map's interior.

Public Land Survey System - Sections

Another grid commonly found on maps is the Public Land Survey System (PLSS) Section Lines. Sections are nominally one square mile in size and oriented with True North. The section number (1 to 36) is often printed in the center of the section. Inexperienced map users sometimes mistake the section line for the UTM grid lines.

The PLSS is not useful as a GPS coordinate system for several reasons.

- It is only used in the Western United States.
- The survey did not include areas with existing ownership claims, such as Spanish land grants.
- The section lines are drawn between the monuments established during the original survey, which started in 1785. Many errors were made due to the rugged and remote terrain and the relatively primitive equipment. The PLSS was used to grant homesteads and other forms of ownership. Thus, the original surveys have persisted to this day, and the section grid is often not uniform or is missing entirely.


Lat/Lon Cross
Indicates the crossing point for 2.5 minute grid lines.
Latitude Tic Mark for 38° 40' N
These tics are spaced 2.5 minutes apart.
Markleeville Peak
Township Boundary
(Strong red line, solid or dashed)
Note the UTM northing nestled in the middle.
Land Section
(Thin red lines, solid or dashed)
Approx. 1 square mile
Described as
Township 9 North, Range 19 East, Section 9
Jeff Davis Peak
1km x 1km
UTM Grid Square
Coordinates given by SW corner
248km E 4280km N
UTM Northing in kilometers
4280km N
Note the unrelated State plane tic mark just to the north.
Lat/Lon of the map corner
38° 37' 30" N Latitude
119° 53' 30" W Longitude
Longitude Tic Mark for 119° 55' W
These tics are spaced 2.5 minutes apart.
UTM Easting in kilometers
247km E.
State Plane Coordinate Tic
These tics are spaced 10,000 feet apart.
UTM Easting in meters
249000m E
UTM Northing in meters
4279000m N
38°37'30"
119°52'30"

Tools to Measure Within the Grid

6

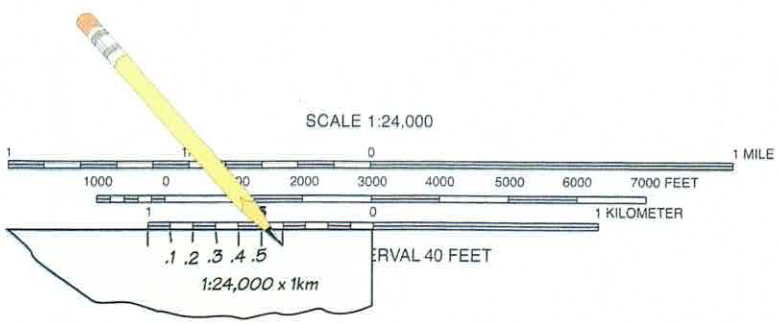
Many different devices and methods exist for measuring position within a UTM grid square. The various techniques vary in both accuracy and ease of use. The basic requirements for all of these tools are that they be scaled to match the map scale, marked to measure metric distance, and sized to match the grid spacing on the map.

Eyeball Estimate

The most straightforward technique is to "eyeball" estimate tenths within the grid. This is relatively easy and requires no special equipment, but it is not particularly accurate.

Map Rulers

Marking a ruler on the edge of a scrap piece of paper is more accurate. Suppose the map has a scale bar marked off in kilometers and tenths of a kilometer. It's easy to transfer these distances to the paper.



Map Scale Math

Without a scale bar, you can do a simple calculation to get the measurements for your paper ruler.

For a 1:24,000 scale map, the calculation would look like this...

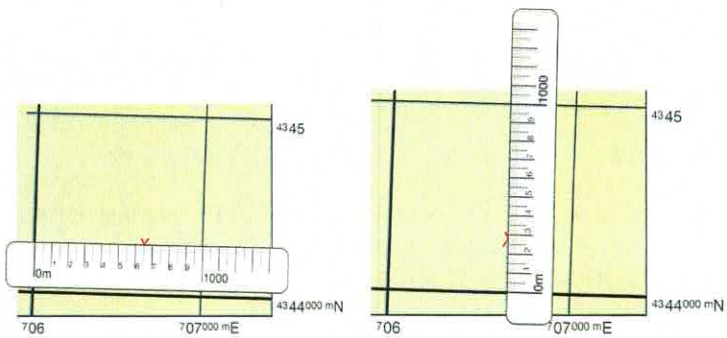
1000m / 24000 X 1000 = 41.6mm

which tells us that a 1000m ruler would be 41.6mm long. The 100m marks on this ruler would be 4.16mm apart.

More generically, the equation is

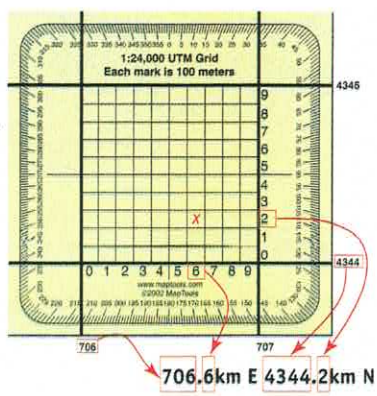
Grid Spacing in meters / Scale Value X 1000 = Length of ruler to match the grid in millimeters.

Whether your ruler is self-made or preprinted, it is used to take two measurements. The easting is measured from the western edge of the grid, and the northing is measured from the southern edge of the grid.



Grid Tool

The grid tool included in this guide is the most accessible tool style for a beginner to learn. Placed into the grid, it allows both the easting and northing to be measured with a single quick and easy tool placement. The disadvantage of this tool style is that it only divides the grid into tenths, less precision than may be desired. This tool style is easy to use with partial grids on the edge of the map.

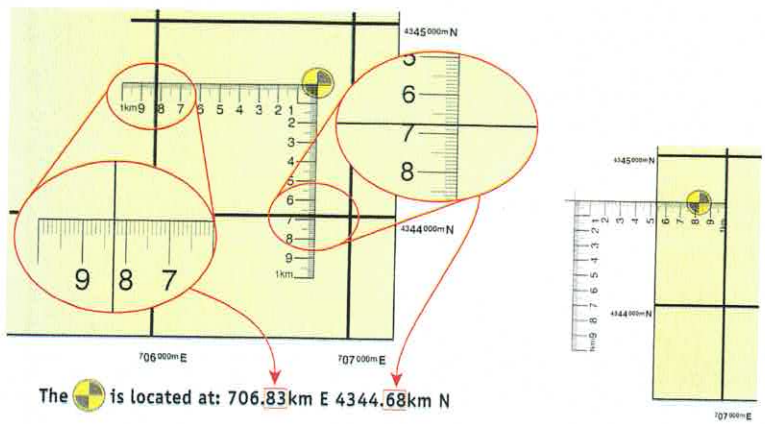


Corner Rulers or Roamers

The next step in the evolution of grid measurement tools is to place two

rulers together at a right angle. This tool is called a corner ruler or a "roamer." The tool is used by placing the corner on the map feature to be measured. With the two rulers parallel to the grid lines, the measurements can be read where the rulers cross the western and southern grid lines. These tools can either be printed onto the corner of a piece of paper or printed onto transparent material with a small hole at the corner to allow marking of the map.

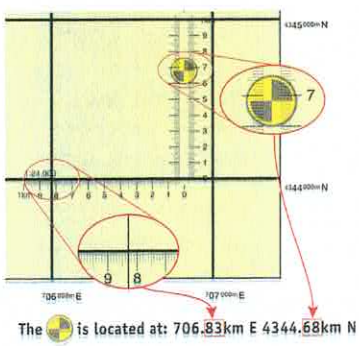
When either the west or south grid line is missing on a partial grid at the edge of the map, the user is forced to use a single ruler aligned on the eastern or northern grid line.

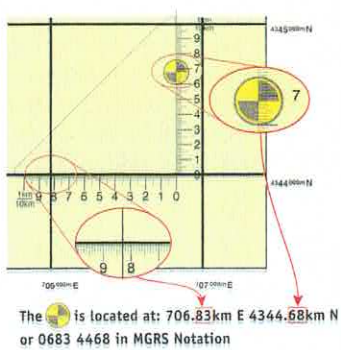


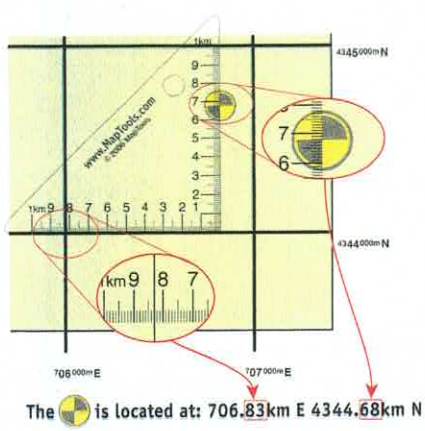
Military Style or Slot Style Tool

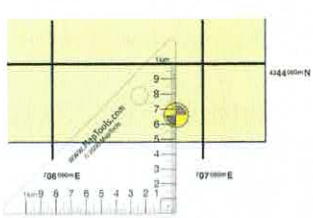
The next evolutionary step was to rotate the two rulers 90°. Now, one of the rulers is placed along the grid's southern edge, while the tool is positioned to align the vertical ruler with the feature to be measured. The easting is read where the horizontal ruler crosses the western edge of the grid. The northing is read where the vertical ruler crosses the feature. This tool has two significant advantages over the corner ruler tool. Keeping the tool parallel to the grid lines is easy, and the vertical ruler confirms that the ruler fits the grid. The latter is essential when there are multiple scales on a single tool. Access to the map varies with the different variations of this tool, including cut-out triangles, slots, or simply the tool's edge.

Once again, when there is a partial grid at the edge of the map, the user may need to revert to separate tool positioning for measuring the easting and northing, with the end of the ruler aligned with whichever grid lines are present.









Two Tools in One

It is easy to use the same UTM tool when the scales are multiples of 10

It's easy to use a single UTM tool on several map scales that are multiples of 10 of each other. For example, a 1:100,000 x 10km tool can be used as a 1:10,000 x 1km tool and a 1:1,000,000 x 100km tool. Just multiply or divide both the scale and the grid distance by 10.

Practice Map

7

You should know enough about using UTM coordinates to try out your skills. Try each problem using both "eyeball estimating" and one or more measuring tools.

The practice map should be tucked inside the back cover of the book. You can download it as a pdf file at MapTools.com/practice-map if it's missing or you need more copies. When you print the downloaded map, be careful not to select any option that would change the map's scale. Examples of options to look out for are "Fit Page," "Adjust to Fit," or a scale of anything other than 100%.

Determine the UTM coordinates for the numbered (1-8) crosshairs on the map with at least 100m accuracy.

The MGRS & USNG chapter has a repeat of this exercise using MGRS and USNG coordinates.

Questions

Answer these questions using the map on the following pages. The grid tool in the back, an improvised ruler made using the scale bar, and any other 1:24,000 scale tools you have are practical and effective in determining coordinates. You should also practice eyeballing an answer to the nearest tenth of a grid or 100m spacing.

Find the map features at the following coordinates:

#9 10S 754789m E 4256648m N

#10 757.7km E 4257.1km N

#11 754880m E 4255170m N

#12 754595m E 4257303m N

Hints and answers are on the next page.

Hints

Units mater

Don't forget to write down the unit of measure and to distinguish the northing from the easting.

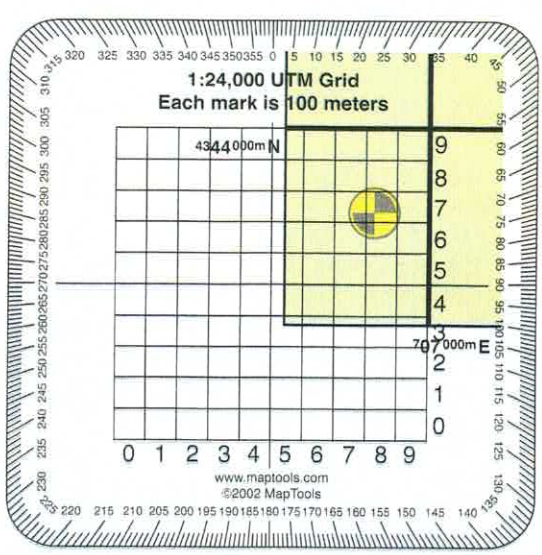
757700 4255300 is not a correct answer.

757700m E 4255300m N (or 757.7 km E 4255.3km N) is the correct answer for 100m precision.

Partial grids at the edge of map

Problems 2, 3, 7, 9, 11, and 12 are in grids where the western and/or southern grid line is missing. That makes measuring the easting or northing from the starting edge harder.

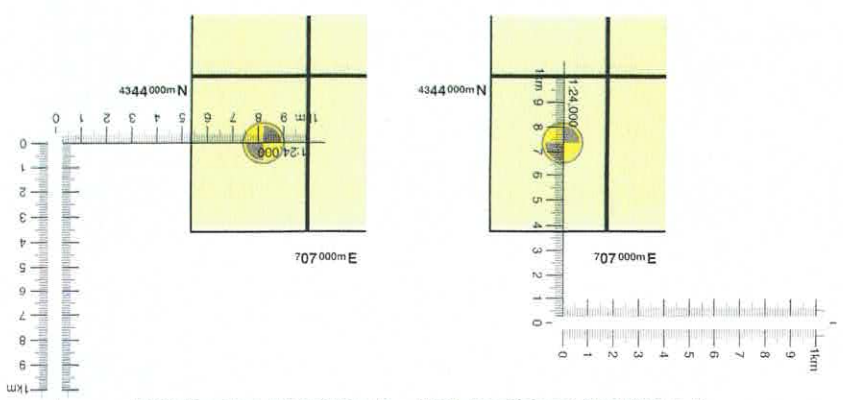
If you are using a grid-style tool, just place the grid into the partial square and let it overhang the missing parts of the grid square.



UTM Easting 706800m E

UTM Northing 4343700m N

If you use a tool with easting and northing rulers scales, you may need to position the tool once for the easting and again for the northing. If the zero meter grid line is missing, align the ruler with the 1000m grid line, and measure backward".



UTM Easting 706820m E UTM Northing 4343730m N

Rounding

Do not round up. If the point being measured falls anywhere within a 100 meter square, use the value for that 100 meter square even when the point is close to the eastern and/or northern edge of the 100 meter square.

In problem 7, the point falls right on the line between the 100 meter squares with the northing values of 400 and 500 meters. An answer with 100 meter precision could end up either 4253400m N or 4253500m N. The 4253500m N is the "more correct" answer because if the point was really exactly on the line, and we measured with more precision, the answer would be 4253500m N. The answer given here decided the mark was a bit south of the line and gave a 10m precision answer of 4253490m N. You will face a similar decision for problem 8.

Answers

#1 757700m E 4255300m N
757.7km E 4255.3km N

#2 758500mE 4253800m N
758.5km E 4253.8km N

#3 756100m E 4254000m N
756.1km E 4254.0km N

#4 754600m E 4253200m N
754.6km E 4253.2 km N

#5 757300m E 4255100m N
757.3km E 4255.1km N

#6 757280m E 4254450m N
757.28km E 4254.45km N

#7 757450m E 4253490m N
757.45km E 4253.49km N

#8 757890m E 4256600m N
757.89km E 4256.60km N

#9 Hells Kitchen Vista
#10 x6580
#11 Sand Flat Campground
#12 Yutaka 7102
#13 x6885

Maps with UTM Coordinates

8

The days when the USGS 7.5-minute 1:24,000-scale topographic maps were often the only maps to use for a backcountry trip are long past. Now, there are dozens of map publishers, and there are often several maps of a given recreation area to choose from. These publishers do not all follow uniform guidelines regarding map scale and coordinate information.

Things to look for in a map you want to use with your GPS and UTM coordinates

The map shows UTM coordinates either as labeled tic marks along the edge or as an actual grid. It is even better if the grid spacing is a multiple of 10 meters. Do not mistake a Public Land Survey System grid for a UTM grid. A Public Land Survey section will be mostly square, sometimes irregular, and measure one mile on a side. The section number (numbers 1 to 36) is often labeled in the square's center. The map datum is printed on the map. If it's not, the most likely datum will be WGS84. See the chapter on *Map Datums* for more information.

The map scale is specified. This could be as a scale ratio, i.e., 1:24,000, or as a distance equivalence, i.e., 1/2 inch = 1 mile. At a bare minimum, you will need a printed scale bar in meters or kilometers.

If it's a digital map, it must be in a format that will preserve scale. PDF is a good choice. Raster formats like tiff, jpeg, bmp, png, etc, may not have preserved the original scale of the map.

If you plan to print the digital file, it needs to be a page size you can print. Scaling the page to fit your printer or paper will cause the map to lose its original scale.

Sources of maps

USGS (United States Geological Survey)

Purchasing printed map sheets from the USGS online store is still possible. It is also possible to download free PDF files for individual map sheets. Beware that the entire map sheet is on a single page, making it

impossible to print without a large-format printer. It may be possible to have the file printed at a local copy or blueprint shop.

Outdoor Equipment Retail Stores and Park "Gift Shops"

The "gift shop" at a state or national park will likely have maps of the park for sale. Some of them will likely be useful for backcountry users. Many local outdoor equipment retail stores stock maps of popular recreation areas in their area.

Online sellers of printed maps

Most map publishers sell their maps from their websites. More popular maps can be found for sale on many other online stores. Using an internet search engine is a good way to find these maps.

Online custom-printed or downloadable maps

My favorite source is CalTopo.com. Their website will allow you to position and scale a map anywhere in the world. They have several different base maps to choose from and plenty of potentially useful layers that can be added. To get a downloadable PDF file of your map, use their "print" feature. You can specify the map scale and several coordinate grid options. The basic features and pdf downloads are free. Larger page sizes, map collections, and other advanced features are available with a paid subscription. They also have an option to order a 12x18 two-sided printed map. A printed map, including shipping, costs $10 when I wrote this.

MyTopo.com offers print-on-demand services for USGS maps, both current and historic, state game management unit maps, and several other collections.

National Geographic touts "Free Printable USGS PDF Topo Maps." But beware. They divide the USGS 7.5-minute, 1:24,000-scale topographic quadrangle onto four letter-sized sheets of paper. But to make that fit, they have to shrink the maps. Worse, the maps shrink by an amount that varies with the map's latitude. So, it becomes very hard to use these maps with your GPS. National Geographic also has a printed series called Trails Illustrated, which are excellent maps of popular recreation areas with UTM coordinate grids.

Here are a few things to watch out for if you are printing your own maps.

Avoid printer settings that say "fit to page" or "scale to fit." These will change the scale of your map, and your coordinate plotting and distance measuring tools will not work as expected.

If you use an inkjet printer with water-soluble ink, keep your maps dry.

A zip-top bag works well for this. If you get your map wet, you'll have a blurry rainbow on a soggy sheet of paper.

Weather and water-resistant paper is available. It works well with laser printers but not so well with inkjet printers.

If you end up with a map with UTM tics on the edges but no gridlines, see this chapter's Drawing the UTM Grid Lines section for tips on drawing in the lines.

If you end up with a map with no UTM coordinate information...

There are two options. You can use your GPS in the field to compute a bearing and distance from one or two known points. Plot these, and you will have your location. See the Using a Map Without a Coordinate Grid chapter. If plotting bearings and distances is too much work for your field conditions, using several points with known coordinates to draw an approximate UTM grid is possible. See the Adding UTM Grid Information chapter for details.

Drawing the UTM Grid Lines

Many USGS topographic maps do not have UTM grid lines printed on them. They do have UTM tic marks along their edges. You will need to draw in the grid lines.

Selecting Your Tools

Using the right tools to grid a map will help you produce a neat-looking and long-lasting map grid. The wrong tools will likely result in smeared ink, grid lines that do not photocopy well, or lines that fade or run when exposed to the elements.

Selecting a work surface

You will need a flat work surface to spread out your map. The surface should be clean and free of holes or cracks that could catch your pen.

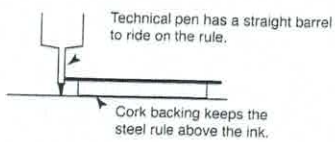
Gridding a map is better done at home or work than at the last minute on the hood of your truck or a nearby flat rock.

Selecting a straight-edge

Your straight edge should be at least 60cm or 24 inches long. This length will span most of the 7.5-minute and 15-minute series topographic maps. You will need a longer straight edge if you need to grid large 1:100,000, 1:250,000, or 1:500,000 scale sheets.

Make sure it is straight. Some poor-quality wooden yardsticks are warped. Hold the straight edge up and sight along the edge. It should appear straight.

Ideally, the edge of the tool you select should be raised off the map's surface. This will keep the edge away from the ink and help prevent smears and smudges. You may accomplish this by using a cork-backed ruler or by placing several layers of tape centered on the bottom of the ruler.



In a pinch, you can roll over the edge of the map to use it as a straight edge.

Selecting a pen

You will want a pen that draws a uniform thin line. You want to select ink that is waterproof, dries quickly to resist smudging, and will not fade over time. A thin, straight barrel will follow the straight edge well. Avoid pens with large tapered ends. They are hard to position along the ruler.

Grid lines that are too thin or made in a light color may not photocopy well.

I've found that a black line 0.2 to 0.25 mm thick works well. Technical drawing pens that meet these criteria can be found in an art or drafting supply store or online.

Good mechanical pencils meet many of these criteria, but their lines do not photocopy well.

Waterproof paper or coatings may make it challenging to draw grid lines. Test your pen on the edge of the map first. I've had good luck using solvent-based pens like an extra fine point Sharpie.

Drawing the Grid Lines

Once your map is laid out and you have your straight edge and pen, you can draw grid lines.

Work slowly and with care. You don't get a chance to erase any mistakes.

Starting at the north edge of your map, locate the UTM grid ticks on your map's east and west edges. The grid line will likely not be parallel to the map's edges. Double-check that the two tick marks you align your

straight edge with have the same UTM coordinate values. Touch your pen down at one of the tic marks, and make sure the ruler is positioned so that the tip is precisely centered over the tic mark. Repeat this check at the other end. Now, carefully draw your grid line. Avoid moving the pen too rapidly for the ink to flow to the tip. Lift your straight edge carefully to avoid smearing your new grid line. Wipe the edge of your rule with a tissue. If you get ink on the tissue, you must be extra careful not to leave smudges as you work. You may need to wipe the edge frequently. Continue working towards the south edge of the map, progressing away from your previous lines. Once you have finished your east-west grid lines, repeat the procedure for the north-south grid lines.

Using Waypoints

9

In addition to displaying your current position, a GPS receiver can store locations. You can store your current location. But even more useful, you can store the location of something you measured the coordinates of on the map. Your GPS calls stored locations waypoints.

The most common use of a waypoint is to put your GPS into GOTO mode, which continuously calculates and displays the distance and direction from your current location to the saved waypoint.

The old-school method of navigating with a distance and a compass bearing pretty much required you to walk in a straight line toward your destination to stay "on course." There were some tricky techniques for navigating around an obstacle, but you still needed to get back on course after passing the obstacle. The more obstacles you needed to go around, the less likely it would be that you would remain on course. Add to that the measuring distance by pacing is, at best, a rough approximation. The old-school methods were difficult and often didn't get you to the desired destination.

With your GPS in GOTO mode to the desired destination stored as a waypoint, you have a continuously updated course direction and distance to your destination. If you need to walk around an obstacle, no problem; do it. Want to take an easier path through the woods? No problem; pick the best path in the general direction of your destination, and your GPS will provide updated directions as you progress.

The bearing and distance displayed by your GPS is a straight line course to your destination. Do not be tempted to follow that straight line. We all know that a straight line across the ground is almost never the fastest or easiest way to get somewhere. You should walk around the thickets of thorny bushes instead of plunging straight through. You should walk around the lake rather than deciding to swim across it. Use your map, your eyes, and your brain to select your route of travel. Use your GPS to keep you heading towards your destination.

There is a small caveat you may need to know about. It relates to the presence or absence of a separate electronic compass in your GPS. If your GPS has a built-in electronic compass, you need to calibrate it every day

that you plan to use it. I've seen an uncalibrated electronic compass off by as much as 90 degrees. Once calibrated, the arrow on your GPS pointing to your destination will point in the correct direction even when you are standing still. Without an electronic compass, you will need to be moving in a mostly straight line for the GPS to know your direction of travel and to point in the direction of your destination. This is because the GPS compares your position from a few moments prior to your current position to calculate your direction of travel.

The computed bearing to your destination will be correct with or without an electronic compass. You could that the computed bearing and use it with your handheld magnetic compass. If you plan to do this, ensure your compass and GPS are set to use the same north reference. For more information on this, see the North Reference section later in this book.

You can also use a stored waypoint to convert between coordinate formats and map datums. Select the coordinate format and datum for your coordinate, and store it in a waypoint. Change the coordinate format and datum to the one you want, and bring up the waypoint. Your GPS will display it in the current coordinate format and map datum.

The instructions and screenshots below are for a Garmin eTrex 20. Your GPS may look and operate somewhat differently, but the concepts should be similar.

Creating a New Waypoint

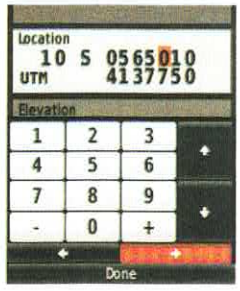
From the main menu, select Mark Waypoint. The Mark Waypoint screen will appear. The waypoint will have a sequential 3-digit number assigned as its default name, and your current location and elevation will be displayed.

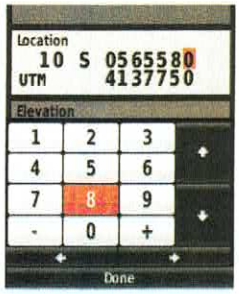
I rarely rename my waypoints. Instead, I write down the waypoint number on my map or notepad.

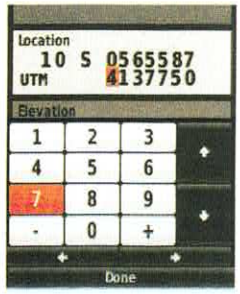
Just press the Done button to save your current location in this waypoint.

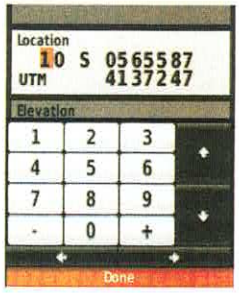
Entering Coordinates for a Waypoint

Mark a new waypoint and select the location. This will bring up a screen to edit the coordinate. Use the right and left arrow buttons to move the cursor between digits. If the location is nearby, you only need to change a few digits of the coordinates. In this example, we are entering a UTM coordinate of 10S 565587mE 4137247mN. Don't let the leading zero on the easting mess you up. Press the Done button at the bottom; when you are finished entering the new coordinate,









Don't forget to press the Done button on the Mark Waypoint screen to save the waypoint.

Entering a Coordinate with a Different Format or Map Datum

It's very common to get a coordinate from someone that

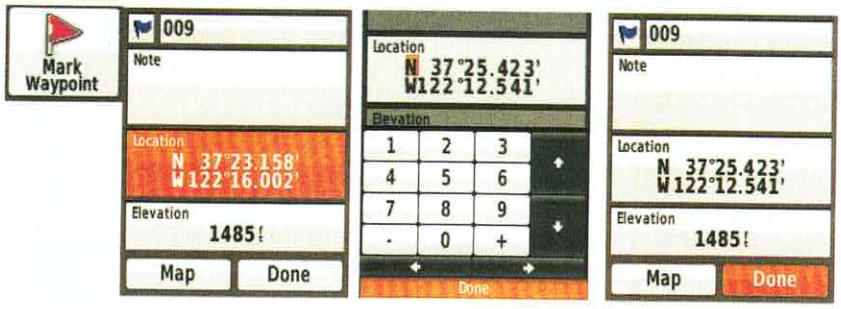
is in a different format or that uses a different map datum than the one you commonly use.

For example, let's put in a lat/lon WGS84 coordinate.

N 37° 25.423' W 122° 12.541' WGS 84

Select Position Format under the Setup icon and set the position format fields to match the coordinate you have.

Select Mark Waypoint to create a new waypoint and edit its location to match your coordinate. The coordinate will be displayed in the format you just set.



Return to the Position Format screen and reset the fields to the values you wish to use.

When you select a waypoint using the Waypoint Manager, it will be converted to display in your newly selected format and datum.

It's a tedious process. You will want to use an online or computer-based coordinate conversion program if you have many coordinates to convert.

Selecting and Navigating to an Existing Waypoint

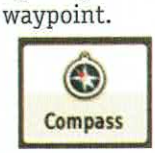
From the main menu, select the Waypoint Manager.

Find and select the waypoint you wish to navigate to.

Select Go to start navigation.

The list will display the distance and bearing from your current location to each waypoint. You can change the sort order of the list using the menu button. Sorting by nearest is often helpful.

The Compass and Map pages can be used to navigate to a waypoint. The data on these pages represents a straight-line course from your current location to the waypoint.



Navigating to a Waypoint

When navigating to a waypoint, your GPSr constantly

calculates a straight line course from your current location to the waypoint you selected.

Remember, a straight line is rarely the best route to follow over land!

I prefer to use the compass page for this kind of navigation.

The Bearing data field is the direction you need to go to reach the waypoint.

The Dist to Next data field is the distance from your current location to the waypoint.

The Destination data field shows the name of the waypoint you are navigating to.

The Heading data field and the Compass Rose both indicate your direction of travel.

The longer pointer in the compass rose points to the waypoint. The shorter arrow is the course deviation indicator (CDI). It indicates how far off course you are. The distance shown at the top right of the compass rose is the distance between dots on the CDI. The start of the course is the location at which the waypoint navigation was started.

Note: The eTrex 10 and 20 do not have an electronic compass. Heading information is only valid when you are moving and is based on the calculated direction between your current location and your location several seconds earlier.

Map Display

When you start navigation to a waypoint, you will end up on the map screen. I usually switch back to the Compass screen. (Too bad there is no way to make that the default.)

I almost always carry a better map of the area than the one in my GPS. So I rarely use the map screen on my GPS. I don't spend my money on GPSs with more map capability or buy maps to install. I don't think I fit Garmin's ideal customer profile.

The small screen and the need to constantly zoom in for detail and out for context makes for a poor map experience.

I do have a topographic map of California on an SD card in one of my GPSs. And I have occasionally needed to use it when I found myself off the printed maps I had brought with me.

Using a Map Without a Coordinate Grid

10

It is not uncommon for a map to lack printed coordinate information. Or maybe it has lat/lon markings, and you want to use UTM coordinates. This chapter presents a technique for plotting your current location on a map without a convenient coordinate grid.

You will need to have a protractor and a straight edge. You will also need to know how to plot a bearing or back bearing with your protractor.

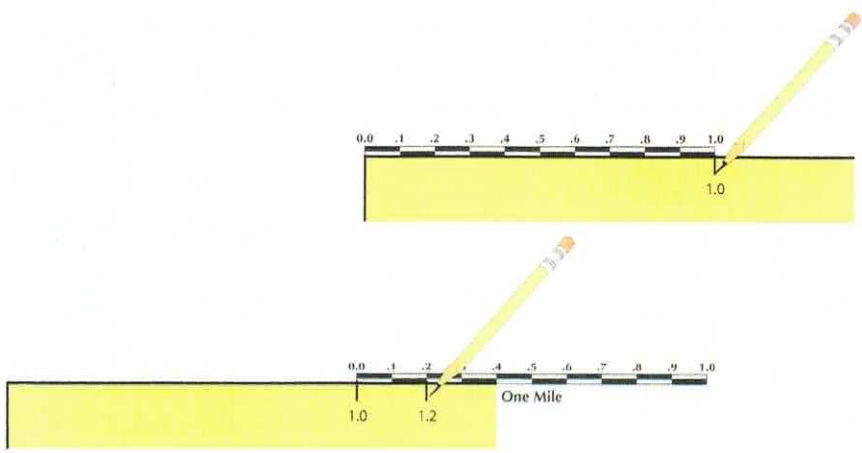
To start, you need to know the coordinates of a known location on the map. There are several ways to accomplish this. Before you leave home, you can use another map or something like Google Earth to determine the coordinates of an easily identifiable feature on the map. Good candidates include peaks or road and trail junctions. You can also use a saved waypoint made at the trailhead. However you determine it, you need the known location marked on your map and stored as a waypoint in your GPS. You can improve accuracy and reduce the chance of plotting errors by using two known points.

Next, you need to figure out how to measure distance on the map. That might be a map ruler that matches the scale of the map. These are available from MapTools. If a scale bar is printed on the map, you can transfer it to the edge of a piece of paper and use that to measure distance.

Finally, ensure you understand what north reference you will use on the map and set your GPS to match. It is useful to draw a north reference line through the known point on the map since that's the location from which you will be plotting bearings.

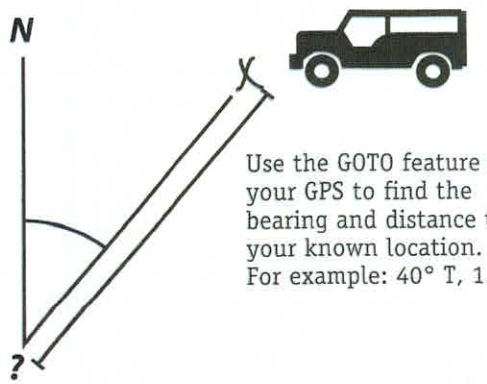
If you are counting on a waypoint saved at the trailhead, remember to do that before you depart on your adventure. Also, don't leave your GPS behind on top of the car. It is easy to walk away while waiting for the GPS to find satellites and then completely forget about it.

Using a 1 mile scale bar to measure 1.2 miles.

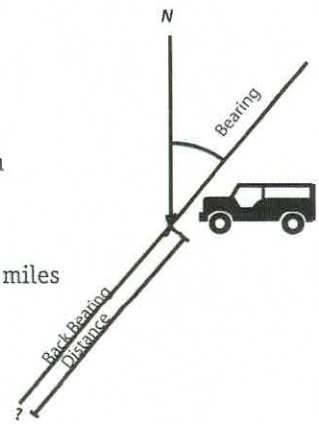


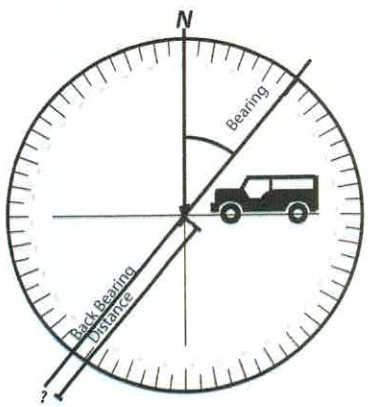
To determine your position in the field

1. Turn on and sync your GPS to get your current position.
2. Note the bearing and distance to the trailhead or other known point.
3. Plot the back direction of the bearing from the known point with your protractor.
4. Measure and mark the distance to the known point.
5. Repeat with a second known location to increase accuracy and confidence.

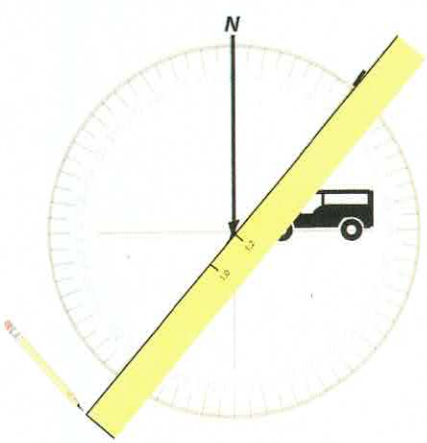


Use the GOTO feature on your GPS to find the bearing and distance to your known location.
For example: 40° T, 1.2 miles





Use a protractor to plot the back bearing from the known point.



Measure the distance from the know point along the back bearing. Mark your current position.

Adding UTM Grid Information

11

Many existing maps do not include UTM coordinate grid lines or markings around the edges of the map. It is possible to add UTM grid lines to a map to make it easier to use in conjunction with your GPS.

The steps described in the following section will produce a UTM grid with sufficient accuracy for most outdoor recreation users. Remember that the grid lines you add are approximations and are likely less accurate than UTM grid information preprinted on a map.

Apologies in advance to any cartographers or surveyors who will likely cringe at the crude nature of this procedure.

Obtaining Some Initial Points with UTM Coordinates

The first step in adding a UTM grid is to find UTM coordinates for several known points on the map. Ideally, you will have at least three points widely separated in the E-W and N-S directions. These first known points can come from existing lat/lon information on the map, they can be transferred from some easily recognized feature on another map with UTM coordinate information, or they can be points you have located using your GPS receiver.

Converting lat/lon reference marks

If the map you place the UTM grid onto already has lat/lon information, you will want to pick several intersections of the lat/lon grid and convert them to UTM.

Transferring known positions from another map

Often, it is possible to find points that are easily identified on both the map you are placing the grid onto and a map that has UTM coordinate information. High points with a monument or benchmark are good choices. Other choices include stream and road junctions.

Locating known position with your GPS

Occasionally, you will need to visit recognizable locations with your GPS to determine the UTM coordinates. Road junctions are not the best choice for a point, but they are frequently used because of their ease of access.

Decide on the Grid Interval

Decide on the grid interval based on the scale of your map. The following table can help you determine the grid interval.

Scale	Grid Interval
Larger than 1:50,000	1km
Between 1:50,000 and 1:100,000	5km
Between 1:100,000 and 1:500,000	10km
Smaller than 1:500,000	Are you sure you want to use UTM?

Recall that map scales represent fractions. So, a 1:25,000-scale map has a scale where every unit of distance on the map is 1/25000 or 0.00004 times smaller than it is on the ground. A 1:25,000-scale map is said to be larger than a 1:100,000-scale map.

1:62,500 scale 15-minute USGS topographic maps typically have UTM grid tics every 1km. Placing grid lines at a 1km interval is tedious and will clutter the map. It is better to choose a 5km interval for these maps.

Grid line spacing less than 25mm (~1 in.) is not recommended.

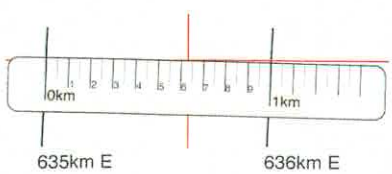
Get a Ruler for the Grid

The next step is to find or build a ruler that matches the map's scale and spans the grid interval you have decided to use. Knowing the map's scale, you can use a ready-made tool. If you have a metric scale bar on the map, you can transfer it to the edge of a sheet of paper. If you have a feet or miles scale bar, you can use it to determine the scale of the map and build yourself a ruler. Refer to Chapter 6 for more details on using "map math" to develop your ruler.

Establishing the Reference Grid Lines

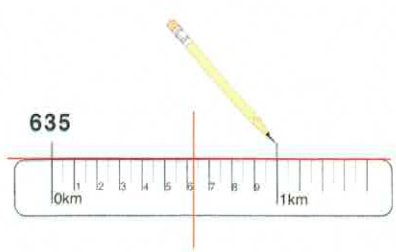
If you were to use a map ruler to measure the position within the grid

of 635.63km E on a map with a 1km UTM grid, it would look something like this:

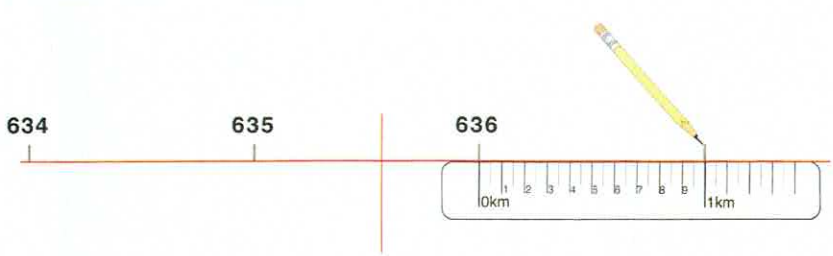


The 635km grid line should be 0.63km to the left of the point, and the 636km grid line should be 1km east of the 635 grid line.

If the grid lines were missing, but you placed the ruler at the point lined up with 0.63km, you could place marks where the grid lines should be.



You can mark the positions for additional grid lines to the east and west by spacing them every kilometer.

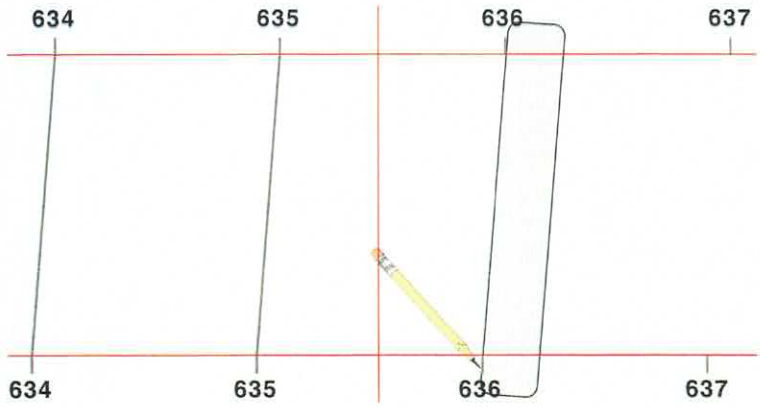


Even though the grid lines are most likely not lined up precisely with true north, you can place the ruler on an east-west line without introducing a significant change in the final position of the grid lines.

Repeat the process of marking the grid line positions with another known point that is north or south of the first point. Ideally, the two points you use will be close to your map's northern and southern edges.

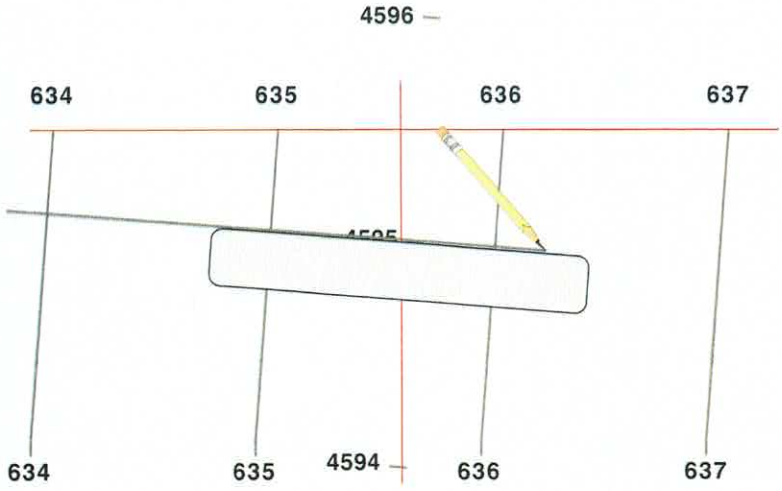
Using two widely space points to establish the grid lines, any angular

difference from true north will be included when you connect the marks as you draw the grid lines



Use a straight edge to connect the marks you have made. Draw in the grid lines. Label them with their UTM coordinate values.

We are using either one of the previous points to position the ruler to determine the initial grid lines for the northing. Because the grid lines we drew in the last step are aligned with Grid North, we do not need a second point to determine the angle. Instead, you can draw these grid lines perpendicular (90°) to the previous grid lines.



If the two known points you have chosen are spaced in the east-west

direction rather than the north-south direction, there is no reason you can't start with the grid lines for the northings.

Ideally, you will have several more known points that you can use to check the accuracy of your work.

A Few Things to Watch Out for...

Errors with the control points

An incorrect UTM coordinate for one of your control points will result in an inaccurate or potentially useless UTM grid.

Map or photo not uniformly scaled

Many raw aerial photographs have not been adjusted to compensate for the scaling effects of the camera position or the different heights of the terrain with respect to the lens. The worse the distortion, the less accurate your grid will be. Photos that have been corrected are referred to as having been *orthorectified* and are often called *orthophotos* or *orthoimages*.

Incompatible map projection on small-scale maps

Any time the lat/lon grid does not appear rectangular, it is unlikely that you can successfully draw in a UTM grid. This is often the case for maps that are 1:1,000,000 or smaller scale.

Two control points are not enough.

Ideally, you would use multiple control points and mathematically adjust the position of the grid you are adding to best fit this larger set of control points. The resulting quality of fit would also give you some idea of the grid's accuracy. Of course, this procedure is typically beyond the abilities of the kitchen table cartographer or the typical wilderness navigator.

Despite these potential pitfalls, creating a useful UTM grid where one did not exist before is often relatively straightforward.

More Details About the UTM Coordinate System

12

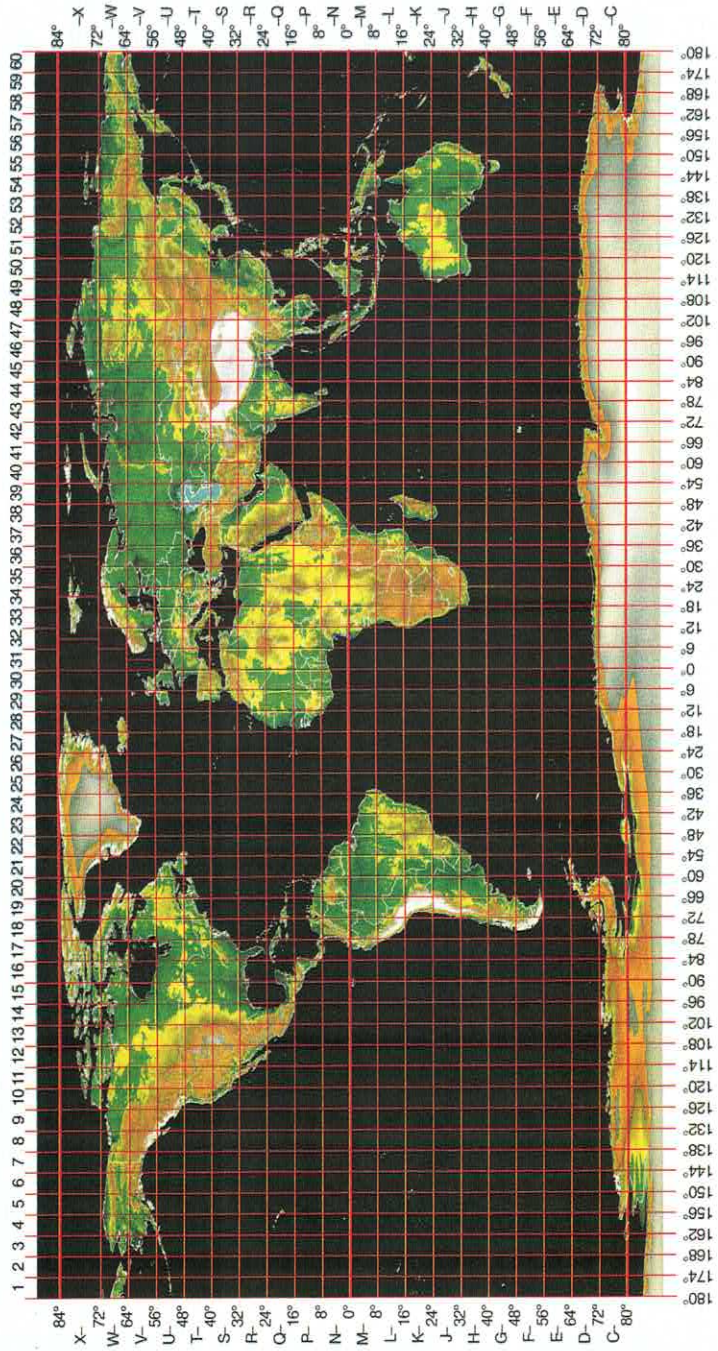
First, distinguish between a map projection and a coordinate grid system. So far, we have been discussing UTM as a coordinate grid. There is also a map projection named the *Universal Transverse Mercator Projection*. A map projection is a method for translating positions on a round earth into locations on a flat map. Projecting the globe onto a flat surface always involves some form of compromise. The most familiar map projection is the Mercator projection, where lines of latitude are shown as straight lines, but Greenland and the polar regions are distorted and are shown much larger than they are in reality. The size of everything is distorted as you move away from the equator.

The UTM projection is the geometric basis for the UTM coordinate grid system. However, it is not uncommon to see a UTM coordinate grid shown on a large-scale map that uses a different map projection. Most users of large-scale maps can ignore the projection of the map. It is uncommon to find a UTM grid shown on maps with a smaller scale than 1:1,000,000.

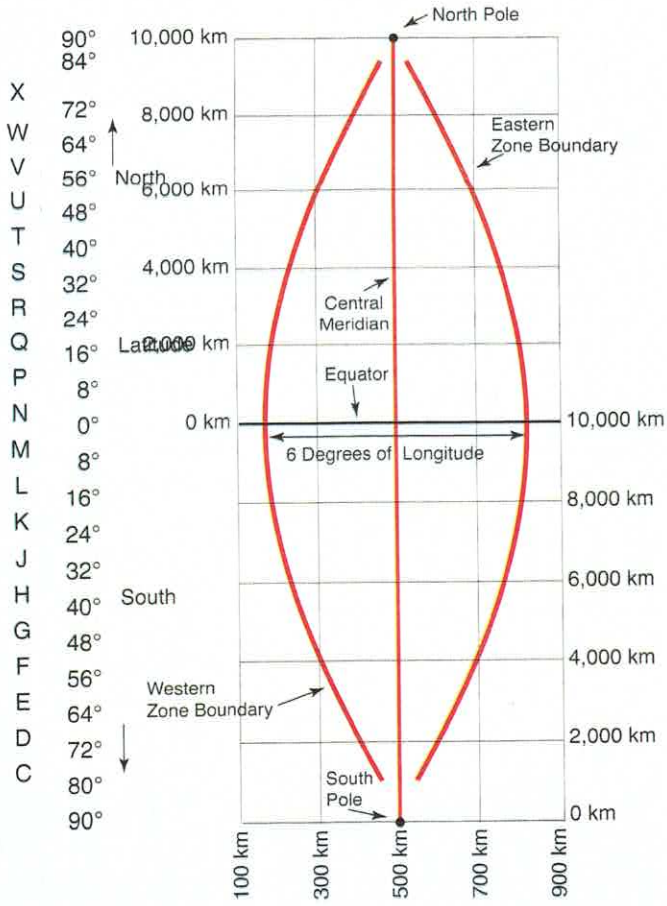
The UTM grid system divides the earth into 60 zones. Each zone is 6° of longitude wide. These zones define the reference point for UTM grid coordinates within the zone. UTM zones are assigned a zone number from 1 through 60, starting at the international date line, longitude 180°, and proceeding east. Zone 1 extends from 180° W to 174° W and is centered on 177° W. UTM zones extend from a latitude of 80° S to 84° N. The Universal Polar Stereographic (UPS) grid system is used in the polar regions. From a user's perspective, UPS coordinates are rectangular measurements in kilometers or meters, just like UTM coordinates.

Note that the zone map shown on the next page uses the Mercator Projection. Latitude and longitude lines are perpendicular, and the polar regions are badly distorted.

Each zone is divided into horizontal bands spanning 8 degrees of latitude. These bands are lettered, south to north, beginning at 80° S with the letter C and ending with the letter X at 84° N. The letters I and O are skipped to avoid confusion with the numbers one and zero. The band lettered X spans 12° of latitude. These letters are known as the Zone Designator Letter or ZDL. The ZDL is necessary to distinguish a coordinate's position between the northern and southern hemispheres.


84° X 72° W 64° V 56° U 48° T 40° S 32° R 24° Q 16° P 8° N 0° M 8° L 16° K 24° J 32° H 40° G 48° F 56° E 64° D 72° C 80°
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60
180° 174° 168° 162° 156° 150° 144° 138° 132° 126° 120° 114° 108° 102° 96° 90° 84° 78° 72° 66° 60° 54° 48° 42° 36° 30° 24° 18° 12° 6° 0° 6° 12° 18° 24° 30° 36° 42° 48° 54° 60° 66° 72° 78° 84° 90° 96° 102° 108° 114° 120° 126° 132° 138° 144° 150° 156° 162° 168° 174° 180°

When the zone number is combined with the letter for the longitude band, the result is called a *Grid Zone Designator* (GZD). A GZD identifies a 6° wide by 8° tall portion of the globe.



Note that there are several exceptions to the zone layout to accommodate the southwest of Norway and the island of Svalbard.

The letters A, B, Y, and Z are used for UPS Grid Zone Designators. UPS coordinates do not have zone numbers.

A square grid is superimposed on each zone. It's aligned so that vertical grid lines are parallel to the center of the zone, called the central meridian.

The zones' central meridian and edges are all meridians or lines of

longitude. In a Transverse Mercator map projection, the central meridian is a straight line between the poles; other lines of longitude run between the poles but are curved. Thus, the edges of the zones are curved lines.

The UTM zone diagram shown is distorted to fit the page. In reality, it is 30 times taller than it is wide. Thus, the zone boundaries are not as dramatically curved as they appear in the diagram.

Eastings

UTM easting coordinates are referenced to the central meridian, assigned an easting value of 500,000 meters East. Since this 500,000m value is arbitrarily assigned, eastings are sometimes called *false eastings*.

An easting of zero, or less than zero, will never occur since a 6° wide zone is never more than 674,000 meters wide.

Minimum and maximum easting values are approximately:

160,000m E and 834,000m E at the equator

465,000m E and 515,000m E at 84° N

Northings

UTM northing coordinates are measured relative to the equator. For locations north of the equator, the equator is assigned the northing value of 0 meters North. To avoid negative numbers, locations south of the equator are made with the equator assigned a value of 10,000,000 meters North.

UTM northing values are duplicated both north and south of the equator. To avoid confusion, the full coordinate needs to specify whether the location is north or south of the equator. Usually, this is done by including the Grid Zone Designator.

If this is your first exposure to the UTM coordinate system, you may find the layout of zones confusing. In most land navigation situations, the area of interest is much smaller than a zone. Thus, the notion of a zone disappears, and we are left with a simple rectangular coordinate system to use with our large-scale maps.

MGRS & USNG

13

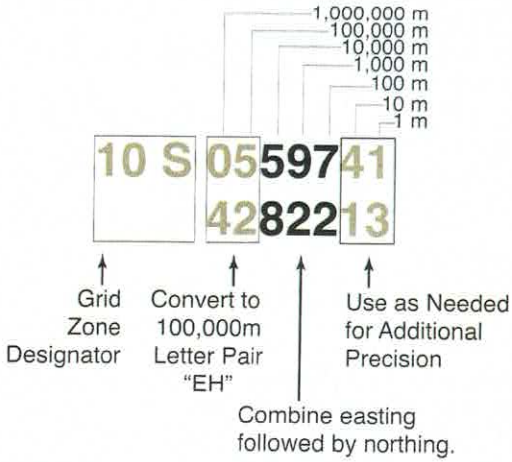
The Military Grid Reference System (MGRS) is a coordinate grid system based on the Universal Transverse Mercator projection and grid system. It was adopted by the U.S. Army in 1949 for designating rectangular coordinates on large-scale military maps and is currently used by the United States and NATO armed forces.

The United States National Grid (USNG) system was proposed in 2000 and adopted as a national standard by the Federal Geographic Data Committee in 2002. USNG is almost equivalent to MGRS when the NAD83 or WGS84 datum is used. Refer to the end of the chapter for details on the differences.

MGRS and USNG are Abbreviated UTM Coordinates

The most common usage of MGRS coordinates is to describe positions within a localized area, such as one covered by a few 1:24,000 map sheets. MGRS is an abbreviated form of UTM grid coordinates at a localized level. This localized coordinate format provides unique coordinates within a 100km square region. This focus on a small area allows us to abbreviate UTM coordinates as follows:

The zone information is dropped. The digits representing 1,000,000m and 100,000m are dropped or converted to a letter pair. The 1m, 10m, and 100m digits are used only to the extent of precision desired.



Full MGRS Coordinate with 100m Precision: **10SEH597822**
Abreviated MGRS Coordinate with 100m Precision: **597822**

Various abbreviated formats for this example would look like:

59 82	Describes a 1000m		by 1000m square.
597 822	Describes a 100m		by 100m square.
5974	8221	Describes a 10m	by 10m square.
59741	82213	Describes a 1m	by 1m square.

The 100m abbreviated format, 597 822, and the 10m abbreviated format, 5974 8221, are the most commonly used.

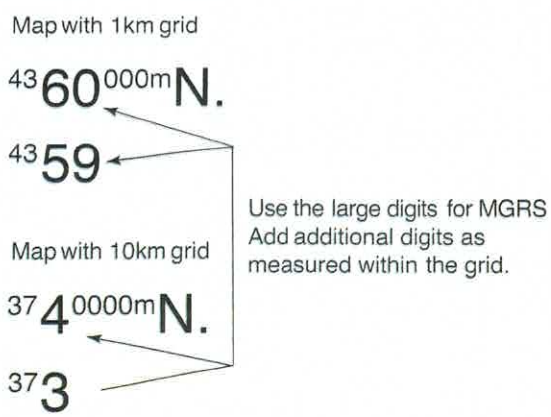
As with UTM coordinates, the easting is reported first, followed by the northing. Remember the phrase "read right up" to help you remember to read the easting from left to right, followed by the northing from the bottom up.

Also, notice that when you abbreviate coordinates, you should not round them. 0559751 becomes 597, not 598. This ensures that your position is still within the reported square. As precision decreases, the square gets bigger.

Typographic Hints for MGRS Users

Maps printed by the Defense Mapping Agency (now called the National

Geospatial-Intelligence Agency) and the USGS show UTM coordinates in a typographic style that aids MGRS users. To read MGRS abbreviated coordinates, the user should use the large typeface digits from the easting and northing and measure within the grid to the desired precision. The smaller typeface digits are not used in the MGRS coordinates.



Setting Up Your GPS for MGRS

Your GPS can also display coordinates in the MGRS format. Select MGRS from the list of position formats in your setup menus. Some GPS receivers allow you to select the precision with which the coordinates are displayed. Typical choices are 100m, 10m, and 1m. Other receivers always display the coordinates with 1m precision.

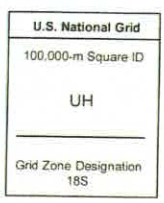
100,000 Meter Square Letter Pair Identifier

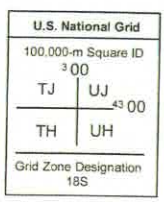
A 6°x8° Grid Zone is broken down into 100,000m x 100,000m squares identified by a letter pair. This letter pair replaces the easting and northing's 1,000,000m and 100,000m digits. The letter pair is unique within a group of 9 adjacent Grid Zones. Again, as with the Grid Zone Designators, the letters I and O are not used to avoid confusion with the numbers 1 and 0.

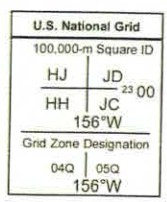
Printed grid reference box

When using a map designed for MGRS users, the information along the edge of the map will contain a Grid Reference Box that will include both Grid Zone Designator and 100,000m square identification information for the map. On most large-scale maps, the entire map will fall within a single Grid Zone Designator. However, that map may fall within several 100,000m square identifications. In this case, the reference box will describe the boundaries and indicate the identifiers for the 100,000m squares within the

map. Small-scale maps may cross grid zone boundaries as well. In this case, the reference box will indicate this as well.







Using the 100,000-meter square letter pair identifier reference chart

If you need to determine the 100km letter pair without the benefit of a GPS or the reference box on the map, you can use the reference table on the following page. Follow these steps:

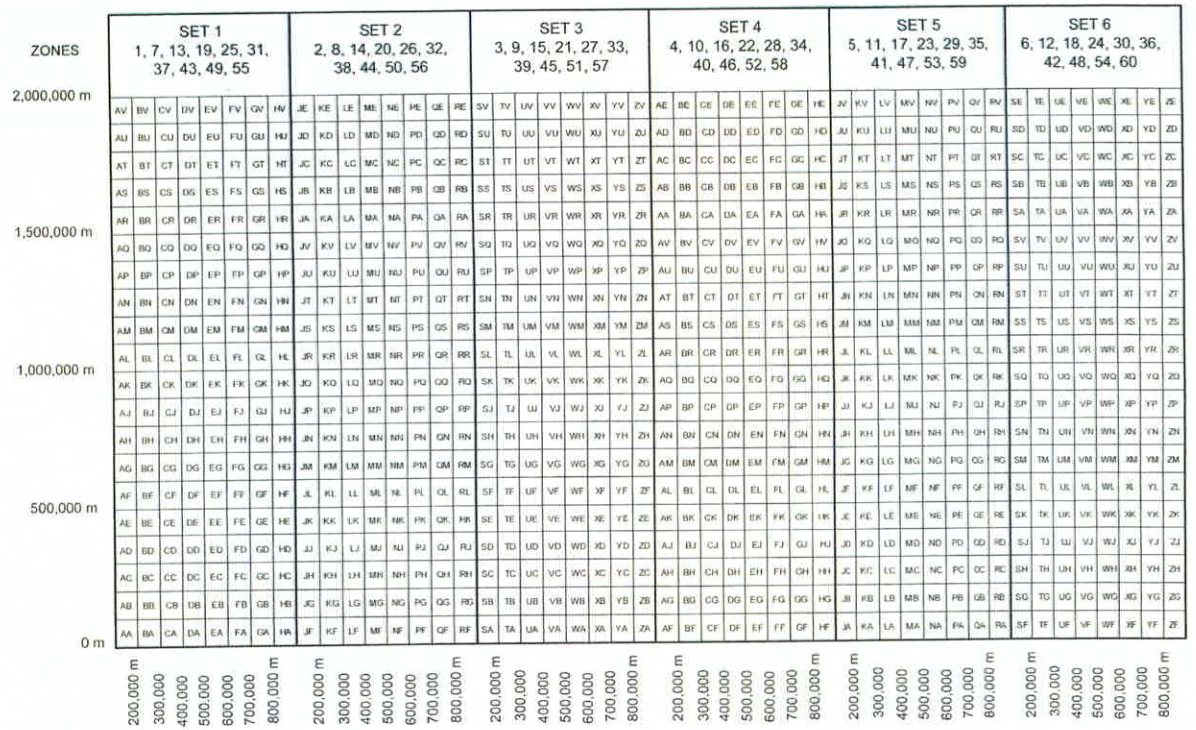
- Locate the Set using the zone number. The table is broken down into six sets. The zone numbers included in each set are listed at the top of the set.

- Use the 100,000m digit of your easting to identify the column within the set that contains your letter pair. The eastings are labeled along the bottom of the chart. This will determine the first letter of the pair. An easting of 703456m E would use the column just to the right of 700,000m E.

- Use the 1,000,000m and 100,000m digits of the northing to locate the row to use. The rows repeat every 2,000,000m. A northing of 3356123m N would use the row just above 1,300,000m N (we subtracted 2,000,000m from the northing.)

- Use the letter pair found within the set, column, and row you identified.

Note that when the map datum is NAD27, the second MGRS Grid Square letter is advanced by 10 letters (remember that I and O are not used). Thus, the second letter in the bottom row of the chart would shift from A to L for even-numbered zones and from F to R for odd-numbered zones. USNG does not follow this odd convention, and the second letter is not shifted for the NAD27 datum.


ZONES
SET 1
1, 7, 13, 19, 25, 31, 37, 43, 49, 55
SET 2
2, 8, 14, 20, 26, 32, 38, 44, 50, 56
SET 3
3, 9, 15, 21, 27, 33, 39, 45, 51, 57
SET 4
4, 10, 16, 22, 28, 34, 40, 46, 52, 58
SET 5
5, 11, 17, 23, 29, 35, 41, 47, 53, 59
SET 6
6, 12, 18, 24, 30, 36, 42, 48, 54, 60
2,000,000 m
1,500,000 m
1,000,000 m
500,000 m
0 m
200,000 m
300,000
400,000
500,000
600,000
700,000
800,000 m

Fully Specified MGRS Coordinates

All the points on the practice map earlier in the book are in Grid Zone 10S. Since the practice map uses the NAD27 datum, the letter pair found in the table, GJ, must be shifted by 10 positions on the chart, resulting in a letter pair of GU. USNG does not use this shift so that the letter pair would be GJ, but the datum notation (NAD27) would follow the coordinate.

Brady Mountain is located at MGRS 10SGU06595862 with 10m precision.

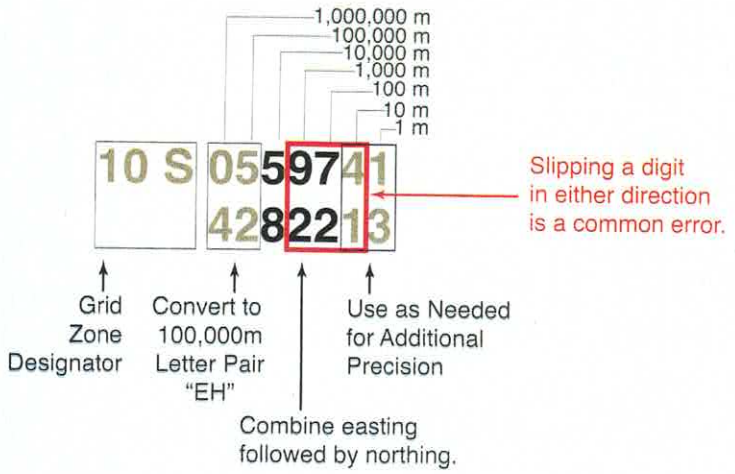
If our activity is all enclosed within grid zone 10S, we can drop the grid zone designator, and our coordinate becomes GU06595862.

If our activity is within the GU 100,000m square, we can drop the 100,000m square ID letters, and our coordinate becomes 06595862.

If 100m precision is adequate, we can drop the 10m digit, and our coordinate becomes 065586.

Some Cautionary Words About MGRS Coordinates

Abbreviated MGRS coordinates may have been valuable when coordinates were sent by Morse code or over scratchy field radios. Their downside is that it is too easy to "slip a digit" and report the wrong digits, resulting in a useless coordinate. Worse yet, there is not enough redundant information to detect that an error may have been made.



Most military and search and rescue folks I work with have quit using

the abbreviated MGRS coordinate format. Most SAR users now report the entire easting and northing as read from their GPS.

Differences Between MGRS and USNG Coordinates

The most significant difference between the two coordinate systems is the second MGRS grid letter shifting when the NAD27 datum is used. USNG does not perform the shift, so the same location will have a different two-letter pair. Since most land navigation users drop the GZD and Grid Letters, the shift usually has little impact unless you need to enter MGRS coordinates into your GPS for far-away locations.

USNG allows the use of only two datums: NAD83/WGS84 or NAD27. The default USNG datum is NAD83/WGS84. When using NAD27, you must explicitly specify it. For example, 10SEH597822 (NAD27). MGRS coordinates may be used with any datum, and there is no formal way to specify it. (It is still very important to specify the datum; it's just not formalized how to write it.)

There are also several minor formatting differences. USNG allows spaces in the coordinate, 10S EH 597 822. MGRS requires that there be no spaces with all of the letters and numbers running together. MGRS allows you to reference an entire 100,000m square area, e.g., 10SEH, whereas USNG requires at least two digits, and thus, the largest area that can be described is a 10,000m square, e.g., 10S EH 5 8.

Finally, the USNG coordinate system only covers the United States and its territories and possessions; it does not include the UPS coordinate system for polar regions or need the zone boundary exceptions defined for Norway.

Many folks have questioned why MGRS was not adopted as the standard by the Standards Working Group of the Federal Geographic Data Committee. Future revisions of the USNG standard may eventually resolve these differences.

Practice Exercise

You should know enough about using UTM coordinates to try out your skills. Try each problem using both "eyeball estimating" and one or more measuring tools.

The practice map should be tucked inside the back cover of the book. You can download it as a pdf file at MapTools.com/practice-map if it's missing or you need more copies. When you print the downloaded map, be careful not to select any option that would change the map's scale.

Examples of options to look out for are "Fit Page," "Adjust to Fit," or a scale of anything other than 100%.

Determine the MGRS or USNG coordinates for the numbered (1-8) crosshairs on the map with at least 100m accuracy.

This exercise uses the same points and map as the UTM-based exercise earlier in the book.

Questions

Answer these questions using the map on the following pages. The grid tool in the back, an improvised ruler made using the scale bar, and any other 1:24,000 scale tools you have are practical and effective in determining coordinates. Answers follow the map. You should also practice eyeballing an answer to the nearest tenth of a grid or 100m spacing.

Find the map features at the following coordinates:

#9 MGRS 10SGT54785664 (NAD27)

#10 577571

#11 USNG 10SGH54885517 (NAD 27)

#12 54595730

Hints and answers are on the next page.

Hints

Map Datum - MGRS

MGRS can be used with any map datum. It's a good idea to specify it, although that is not a strict requirement. There is a special exception for the NAD27 datum. That means the second letter of the Grid square gets advanced by 10 letters (omitting I and O) for MGRS. The map for this exercise uses the NAD27 datum.

Map Datum - USNG

USNG is only used with NAD83/WGS84 or NAD27 map datums. The assumed datum is NAD83/WGS84. If NAD27 is used, it must be specified.

It is common, but not technically correct, to leave off the datum when writing abbreviated coordinates without the GZD and the 100,000m letter pair.

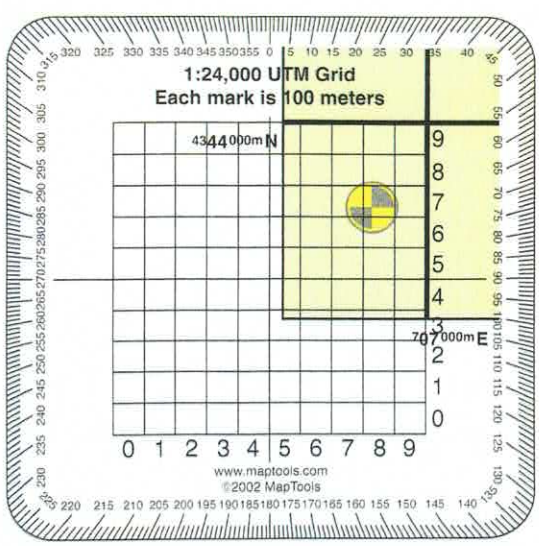
Units are left off

Neither MGRS nor USNG coordinates include the measured units or distinguish the easting and northing. MGRS goes a step further and does not allow spaces within the coordinate.

Partial grids at the edge of map

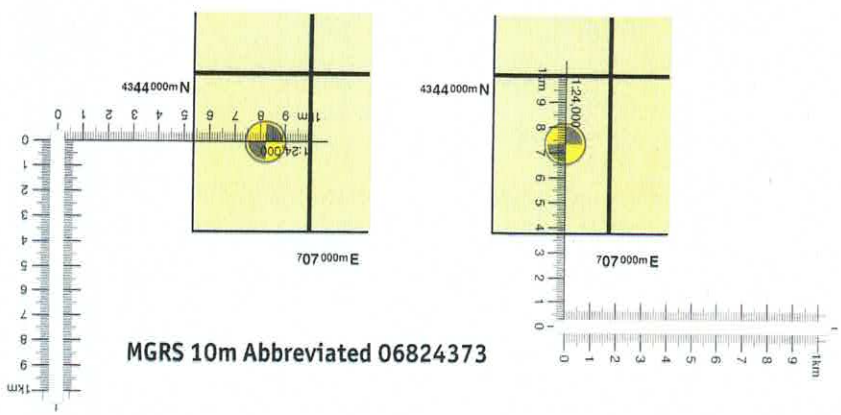
Problems 2, 3, 7, 9, 11, and 12 are in grids where the western and/or southern grid line is missing. That makes measuring the easting or northing from the starting edge harder.

If you are using a grid-style tool, just place the grid into the partial square and let it overhang the missing parts of the grid square.



MGRS Abbreviated 100m 068437

If you use a tool with easting and northing rulers scales, you may need to position the tool once for the easting and again for the northing. If the zero meter grid line is missing, align the ruler with the 1000m grid line, and measure backward".



MGRS 10m Abbreviated 06824373

Answers

(Full coordinate and, 10m, 100m, 1000m abbreviated)

#1 MGRS 10SGT5770055300 (NAD27), 57705530, 577553, 5755
USNG 10SGH57700 55300 (NAD27), 5770 5530, 577 553, 57 55

#2 MGRS 10SGT5850053800 (NAD27), 58505380, 585538, 5853
USNG 10SGH58500 53800 (NAD27), 5850 5380, 585 538, 58 53

#3 MGRS 10SGT5610054000 (NAD27), 56105400, 561540, 5654
USNG 10SGH56100 54000 (NAD27), 5610 5400, 561 540, 56 54

#4 MGRS 10SGT5460053200 (NAD27), 54605320, 546532, 5453
USNG 10SGH54600 53200 (NAD27) ,5460 5320, 546 532, 54 53

#5 MGRS 10SGT5730055100 (NAD27), 57305510, 573551, 5755
USNG 10SGH57300 55100 (NAD27), 5730 5510, 573 551, 57 55

#6 MGRS 10SGT5728054450 (NAD27), 57285445, 572544, 5754
USNG 10SGH57280 54450 (NAD27), 5728 5445, 572 544, 57 54

#7 MGRS 10SGT5745053490 (NAD27), 57455349, 574534, 5753
USNG 10SGH57450 53490 (NAD27), 5745 5349, 574 534, 57 53

#8 MGRS 10SGT5789056600 (NAD27), 57895660, 578566, 5756
USNG 10SGH57890 56600 (NAD27), 5789 5660, 578 566, 57 56

#9 Hells Kitchen Vista

#10 x6580

#11 Sand Flat Campground

#12 Yutaka 7102

#13 x6885

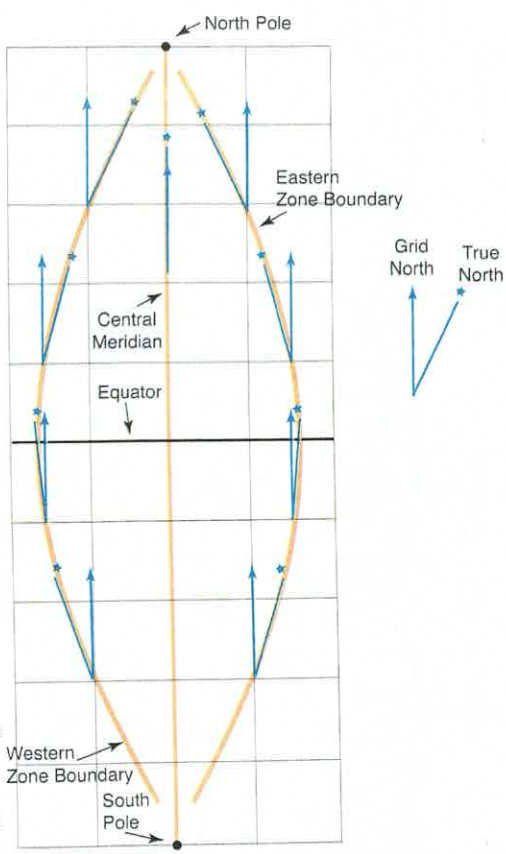
North Reference

14

The use of the UTM coordinate system also introduces a new north reference. In addition to True North and Magnetic North, we can now refer to Grid North. Grid north is the direction that the North-South UTM grid lines run. Grid North is typically within 2 degrees of True North.

Grid North is practical because the map has many Grid North lines. They make convenient north reference lines when we use our compass to plot or determine bearings from the map. Often, the only True North reference lines on the map are the left and right edges.

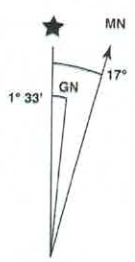
Revisiting the UTM Zone Diagram will help explain how Grid North differs from True North. First, recall that all longitudinal meridians are also True North reference lines. The edges of the UTM zone and the central meridian are all longitudinal meridians, shown in red on the zone diagram.



At the center of the zone, the UTM grid lines are aligned with the central meridian; thus, there is no difference between Grid North and True North at the center of the zone. The further we move from the central meridian, the more significant the difference between Grid North and True North, with the maximum difference occurring at the zone's edges. This difference also becomes more

significant as we move towards the poles and away from the equator. Depending on the location within the zone, Grid North may be either east or west of True North. The difference between Grid North and True North within the Continental United States will be at most two degrees.

The declination diagram found on most maps shows the relationship between True North, Magnetic North, and Grid North. Magnetic declination varies over time, while Grid North is related to the zone geometry and does not change over time.



Most GPS receivers can be set to display heading information relative to True North, Grid North, an automatically calculated Magnetic North, or a user-specified Magnetic North.

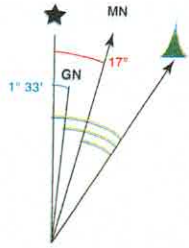
When using Grid North as the north reference on your map, you will want to use the difference between Grid North and Magnetic North as the value you use in calculating magnetic bearings or that you set into your compass.

It is also prevalent to ignore everything you've just read, use the grid lines as if they are True North lines, and live with the degree or two of error that may result.

The UTM zone diagram shown is distorted to fit the page. In reality, it is 30 times taller than it is wide. Thus, the zone boundaries are not as dramatically curved as they appear in the diagram, nor is the difference between Grid North and True North as significant as it seems.

Converting between north references

The key to converting between the three north references is to add a line representing the bearing to an imaginary target to the declination diagram. Now it is easy to see the different angles measured to the target from each north reference.



In the example at the right, both Magnetic and Grid North are east of True North. A True bearing would be 17° larger than a magnetic bearing. Thus, to convert from a Magnetic bearing to a True bearing, you would add 17°.

The angle measured from the target to Grid North is also larger than that measured from the target to Magnetic North. The difference is the 17° angle from True North to Magnetic North less the 1° 33′ angle from True North to Grid North. Thus, to convert from a Magnetic bearing to a Grid North reference, you would add 15° 27′. (I would likely round this to 15 1/2°. I might even round to 16° if accuracy was not critical.)

Plotting a bearing on the map relative to Grid North

UTM grid lines make great north reference lines to use when plotting or measuring bearings on a map. They are often spaced every kilometer, so there are many of them across the map, and it is easy to find one near the point from which you are plotting the bearing. If your bearing is not measured relative to Grid North, be sure to convert it before plotting. You may want to adjust your GPS and compass to display bearings relative to Grid North.

Plotting a bearing using a protractor

A protractor is the easiest and most accurate method of plotting a bearing onto a map. Most protractors are marked in one-degree increments, and there are no moving parts to confuse you. Many MapTools' coordinate plotting tools have a protractor on their outer edge.

Steps to plot a bearing using a protractor

- Put the protractor's center on the point from which you are plotting the bearing.
- Align the zero-degree mark, or use some of the parallel north-south lines on the protractor with a UTM grid line.

The protractor is now set up to measure angles relative to Grid North.

- Place a small mark on the map at the edge of your protractor next to the mark corresponding to the bearing you are plotting.

- Use a ruler or other straight edge to draw a line between the point you plotted from and the make you made at the protractor's edge. Extend the line as needed.

Plotting a bearing using your compass as a protractor

If you have a clear base plate compass with a straight edge, you can use it as a protractor without needing to use the magnetic needle or align the map with Grid North. You use the parallel lines on the bottom of the compass to align the protractor with the Grid North line on your map. This technique tends to be less accurate and more error-prone than using a protractor.

Steps to plot a bearing using a compass as a protractor

- Turn the compass dial to align the bearing to be plotted with the direction of travel arrow.

- Rotate the entire compass to align the parallel lines in the bottom of the compass capsule so they are parallel to the UTM grid lines. If you have adjusted your compass to read bearing in a north reference other than Magnetic North, the capsule arrow you box the needle in will not point to zero degrees. Do not use this arrow to align the compass parallel to the grid lines. NOTE: The magnetic needle is not used and may point in any direction. We do not need to orient the map with North.

- Position the edge of the compass on the point from which you are plotting the bearing while keeping the compass aligned with the Grid North lines.

- Draw a line along the edge of your compass passing through the plotting point. Extend the line as needed.

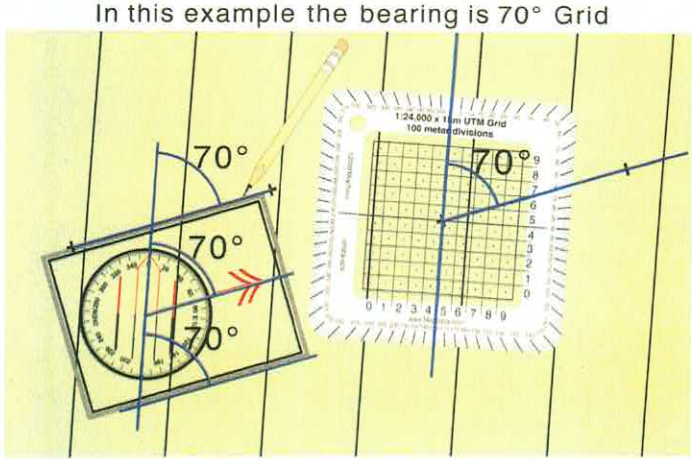
Plotting a bearing using your compass and aligning your map with your chosen north reference

Plotting a bearing by aligning both your map and your compass using the magnetic needle is also possible. If you use a compass without a transparent base, like a lensatic compass; this may be the only way to plot using your compass. This technique is both complicated and error-prone.

You must accurately align the map to north and align your compass to the bearing to plot using its magnetic dial. All while avoiding any metallic interference like a bolt in the table you have the map set on, the clip on your clipboard, or the pen in your hand.

More detailed tutorials exist on plotting a bearing onto your map using each technique at MapTools.com/tutorials/plotting/plotting-a-bearing.

Example of Plotting or Measuring Bearings on the Map
Using Grid North as the North Reference
In this example the bearing is 70° Grid



- Rotate the compass dial so that 70° is at the index line.
- We're not using the magnetic needle in our compass.
- Instead we are aligning the parallel lines, in the compass capsule, with the Grid North reference lines on the map.
(The Grid North angle has been exaggerated for clarity)

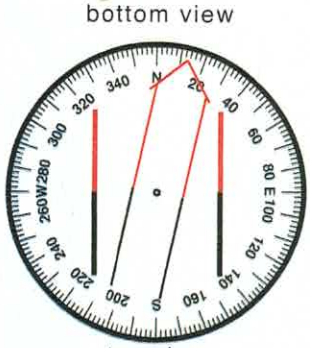
Setting up your compass to read relative to Grid North

If you choose to plot your bearing using Grid North as your north reference, you will likely want to adjust your compass to use Grid North as well. Compasses, where the "needle boxing" arrow can be rotated away from zero degrees, can be adjusted to read bearing relative to north references other than Magnetic North. The adjustment is usually one of two types. A tiny rack and pinion gear driven by a tiny screw head on the dial or a friction fit between the dial and the capsule.

To use Grid North, you must adjust your compass for the difference between Magnetic North and Grid North. It is important to remember that Grid North varies as you move within a UTM zone and that Magnetic North varies as you move relative to the Magnetic North Pole, which also moves slowly over time. **This is not a "set it and forget it" adjustment.** At a minimum, you need to check the adjustment for correctness at the beginning of every adventure. You must also remember to add the north reference to the end of every bearing when you write it down or communicate it to someone else.

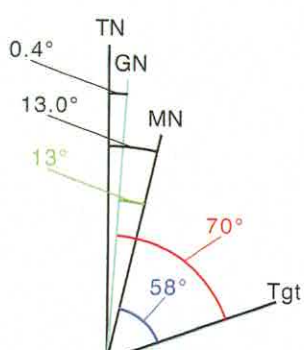
Setting Up your Compass
With a 13° E Offset
to Measure Relative
to Grid North

bottom view



top view

Declination Reference Card for
N 37.5° W 122.3°
June, 2024



Bearings Measured Relative to GN
are 13° larger
than bearings measured relative to MN
(small angles have been exaggerated for clarity)
(values rounded to the nearest degree)
MapTools.com/declination

Custom Declination Ref Cards from MapTools

You can download a current declination reference card customized to your choice of north reference for any location in the world at:

MapTools.com/declination.

The reference cards contain:

- A map showing the general location and the nearby difference between Magnetic North and either True North or Grid North.
- An example of plotting onto a map using your selected north reference
- A compass set-up diagram
- A declination and grid variance diagram
- Conversion formulas between the north references you selected to use with your man and compass.

UPS

15

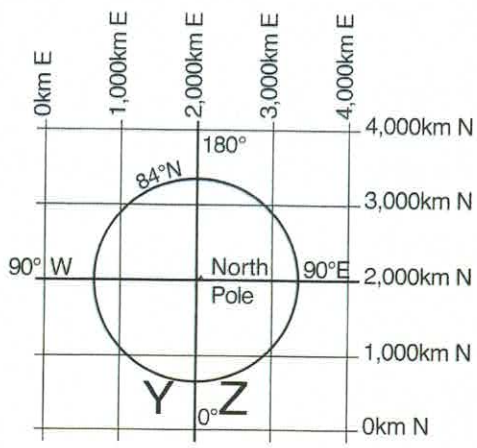
In the polar regions above 84°N and below 80°S, the coordinate system used is the Universal Polar Stereographic (UPS) system.

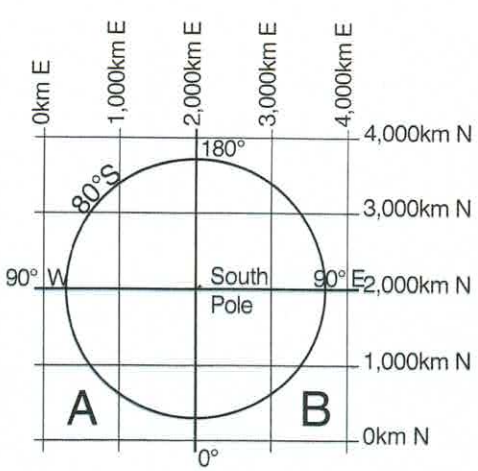
UPS is also a square grid system, but it is placed over a polar stereographic projection centered on the pole. The poles are assigned a false easting and a false northing of 2,000km. The East-West direction is defined by the 90°W to 90° E lines of longitude, and the North-South direction is defined by 0° to 180°

At the North Pole, a Grid Zone Designator of 0Y is used "west" of the pole, and 0Z is used "east" of the pole. At the South Pole, it's 0A to the "west" and 0B to the "east."

Your GPS is designed to seamlessly switch between UTM and UPS depending on the displayed location. You can quickly test this. Store a waypoint in lat/lon format above 84° N or below 80° S. Then switch back to UTM/UPS and bring up the waypoint.

A large-scale map user can accurately plot UPS coordinates just like they would plot UTM coordinates. The definitions of East and North might seem a bit unconventional, but it is still "read right then up."


0km E
1,000km E
2,000km E
3,000km E
4,000km E
4,000km N
3,000km N
2,000km N
1,000km N
0km N
180°
84°N
90° W
North
Pole
90°E
Y
Z
0°


0km E
1,000km E
2,000km E
3,000km E
4,000km E
4,000km N
3,000km N
2,000km N
1,000km N
0km N
180°
80°S
90° W
South
Pole
90° E
A
B
0°

Scale Reference

16

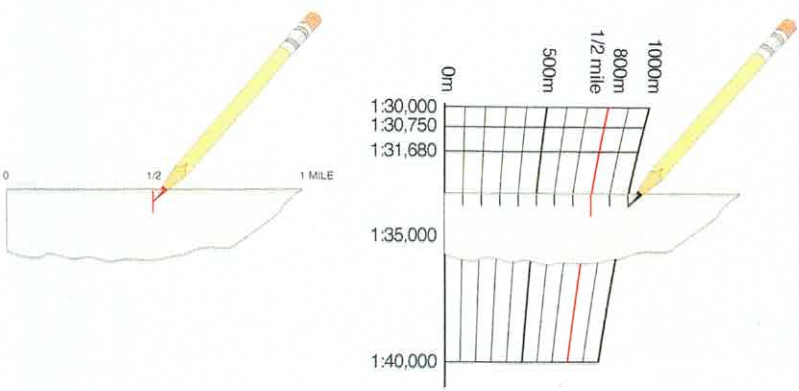
Maps come in an infinite variety of scales. In some cases, the map may not even list its scale. *The charts on the following pages can be used to create a UTM measuring tool along the edge of a scrap of paper for many* different scales of maps.

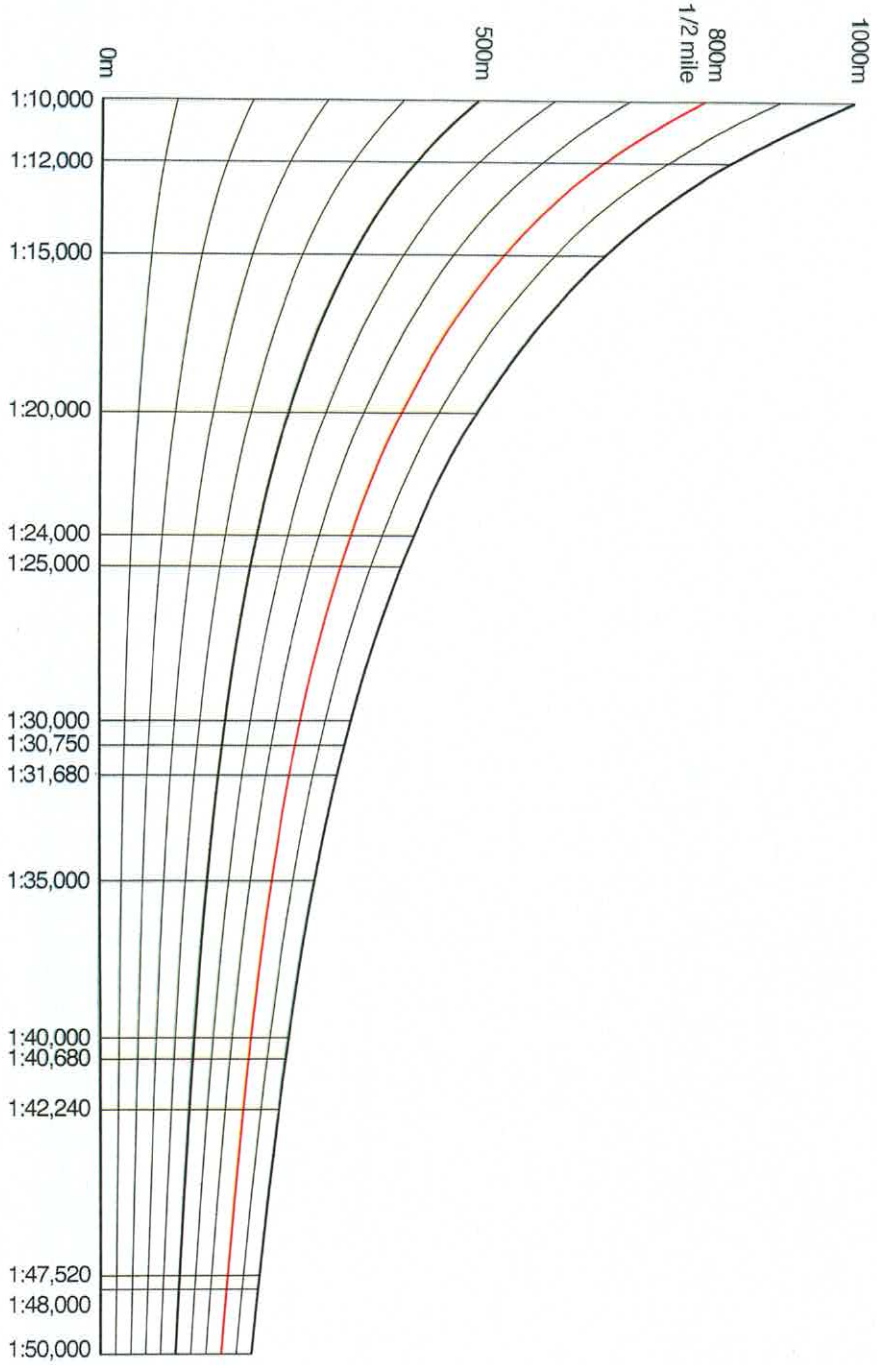
If the map has a metric scale bar, mark a 1-kilometer distance on the edge of your scrap paper. Slide your 1-kilometer mark along the diagram until it fits. Transfer the lines from the diagram to the paper, and you have a 100-meter measuring tool for your map.

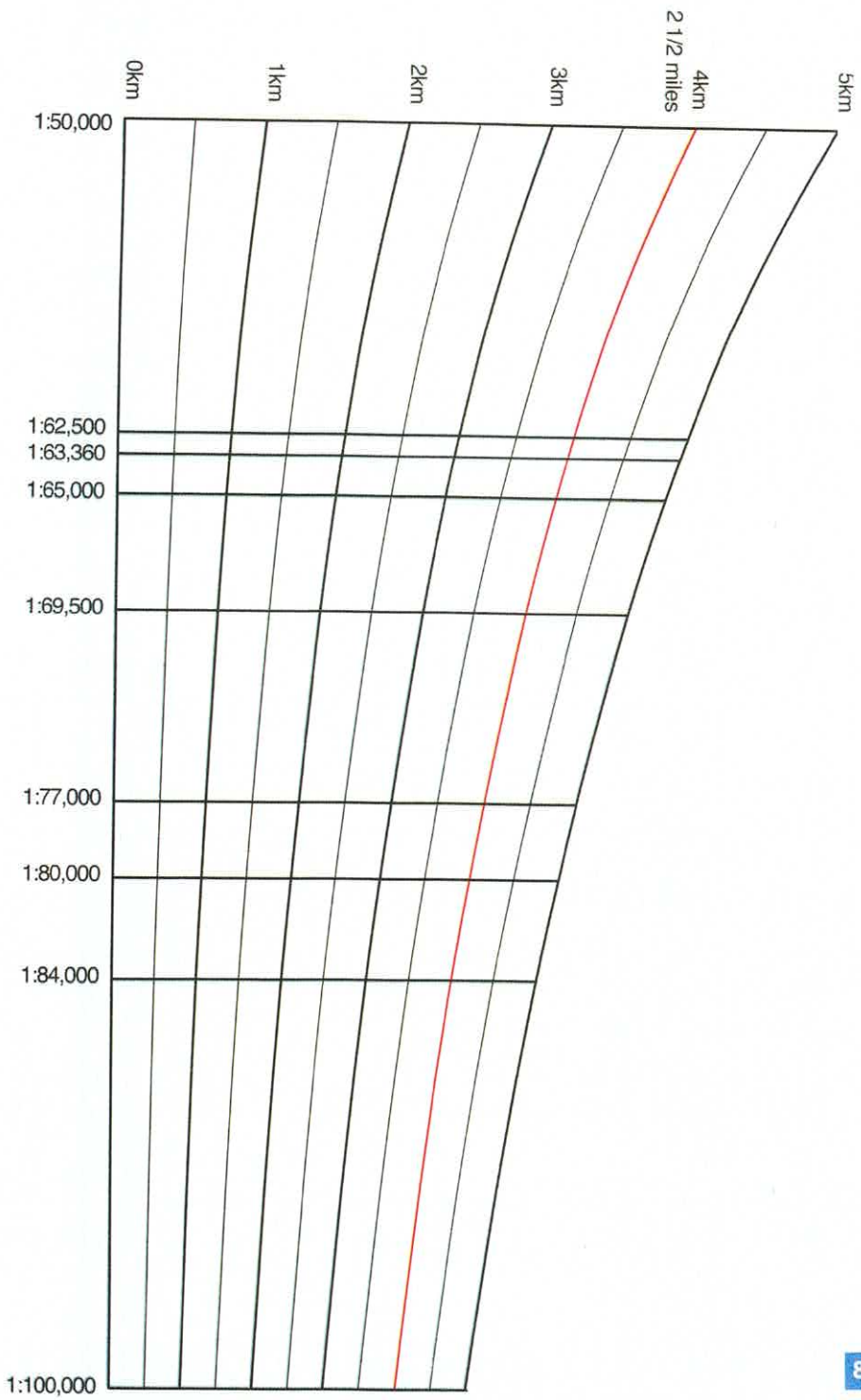
Even if your map only has a mile scale bar, you can still create an accurate measuring tool. Mark a 1/2 mile distance on the edge of your scrap paper, align it with the 800m line on the diagram (shown in red), and transfer the lines. Rest assured, you now have a reliable 100m measuring tool for your map.

For scales between 1:50,000 and 1:100,000, mark 5km or 2 1/2 miles and use the diagram on page 50 to produce a 5km measuring tool. If you want a 10km tool, slide the tool over and add another set of 5km markings.

Remember you can use these diagram at a factor of 10, larger or smaller. The 1:10,000 to 1:50,000 by 1000m diagram can be used as a 1:1,000 to 1:5,000 by 100m diagram or a 1:100,000 to 1:500,000 by 10km diagram.




0m
500m
800m
1/2 mile
1000m
1:10,000
1:12,000
1:15,000
1:20,000
1:24,000
1:25,000
1:30,000
1:30,750
1:31,680
1:35,000
1:40,000
1:40,680
1:42,240
1:47,520
1:48,000
1:50,000


0km
1km
2km
3km
2 1/2 miles
4km
5km
1:50,000
1:62,500
1:63,360
1:65,000
1:69,500
1:77,000
1:80,000
1:84,000
1:100,000

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UTM Grid Tool for 1:24,000 scale maps

The inside back cover has a pouch that should include a plotting tool, typically a 1:24,000 Grid Tool. This versatile tool measures UTM coordinates on a 1:24,000-scale map with a 1km grid size. It can be used with the practice map in this booklet and the most common series of USGS topographic maps for the continental United States, giving you the power to navigate with ease.

MapTools offers other scales and different styles of tools. Visit our website at MapTools.com for more information.

Practice Map

Tucked inside the back cover you should find a practice map. If it missing, visit MapTools.com/UTMBook to download a copy or purchase additional copies. If you print you own, be careful to preserve the scale. Do not select any "fit to page" or scale to fit options.